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# AIRPORT TRANSPORTATION

***A Study of Transportation Means Between Airports and the Metropolitan Areas They Serve***



HSR-RR-61/5-MS
February, 1961



Prepared under Contract FAA/BRD-203
for:
Bureau of Research and Development
Federal Aviation Agency
National Aviation Facilities Experimental Center
Atlantic City, New Jersey

HSR human sciences research inc
FILLMORE AND WILSON BOULEVARD
ARLINGTON 1, VIRGINIA

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***A Study of Transportation Means Between Airports and the Metropolitan Areas They Serve***

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*This report has been prepared by Human Sciences Research, Inc., for the Bureau of Research and Development, Federal Aviation Agency, under Contract No. FAA/BRD-203. The contents of this report reflect the views of the contractor, who is responsible for the facts and for the accuracy of the data presented herein. The contents do not necessarily reflect the official policy of the Bureau of Research and Development or the Federal Aviation Agency.*

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# FOREWORD

The prime objective of the airline passenger is to move from origin to destination more quickly and safely. Time in transit can be subdivided into two parts: time in air, and time spent between local origin or destination and the airport.[1] Hundreds of million dollars have been invested to develop faster aircraft which reduce time in air. Funds of similar magnitude have gone into facilities needed for safe accommodations for larger and faster jet aircraft. The result of this investment over the last two decades has been to reduce, significantly, the time of air travel: the link in the transportation chain that has received concerted attention.

Meanwhile, little attention has been given to the other link, that between origin or destination and the airport. Airport transportation traffic problems are being compounded. Airports are being moved farther from cities and metropolitan traffic problems are increasing in intensity with the result that the time the average passenger spends getting to and from the airport may be actually increasing. In any case, as air travel time is reduced the proportion of total trip time required for airport transportation is increased.

There is good reason to believe that the growing gap between the technology of air travel and that of airport transportation will have an impact on the popularity of air travel, especially in the short-haul market: on its economics; on the procurement and staffing plans of

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[1] There is no entirely satisfactory word which denotes the travel between local origin or destination and an airport. We have used the words ground travel and airport transportation interchangeably, even though the advent of helicopters makes ground travel an inaccurate term in some instances.

airlines; on requirements for air traffic control facilities; and for estimates of the number and training of personnel required to man them. Because the area has been studied relatively little, pertinent data that would support these conclusions are hard to find. However, strongly suggestive data may be drawn from several sources. For example, a 40% decrease in passenger volume accompanied the shift of the Detroit Airport from 6 miles from the city to Willow Run, 31 miles away. (See footnote on page 230). Thereafter, traffic continued to increase with national averages but never at the level that would have been predicted before the move. Admittedly, the Detroit study does not establish conclusively the impact of long airport transportation time on air travel on a national basis. It is cited here because it dramatically suggests this impact in one specific case, and because, as the only study we could find of its sort, it illustrates the dearth of knowledge of airport transportation problems and their influence on air traffic volume.

Certainly, to the extent that these problems of airport transportation influence air travel volume, neither the airports, the airline industry, nor the Federal Aviation Agency can afford to ignore this influence in their plans and projections. The severity of the problems depend on the pertinent facts and, to some extent, on their interpretation. To obtain these facts, questions such as these must be asked and answered:

1. Where do airport users come from and go to, in the area served by the airport?

2. How do they get to and from the airport?

3. How much time does it take?

4. What are the costs involved?

5. What do passengers think about airport transportation?

6. What influence does airport transportation have on the air travel market?

7. What is the prognosis for airport transportation?

8. What import does the advent of multi-airport cities and new airports being built farther from the city have?

9. What effects on airport transportation can be expected from the changes occurring with metropolitan transportation in general?

The purposes of this report are to obtain answers to these and similar questions by collection and presentation of facts about airport transportation, and to devise objective means by which to compare the performances of existing and proposed airport transportation systems.

Airport transportation is one element of the country's total transportation system and, as such, suffers from the ills and problems of the total system. The report of the transportation conference sponsored by the National Academy of Sciences in 1960 throws these problems into sharp relief:

> "Every aspect of our national life--now and in the future--involves the coming together of people, the accessibility of resources, the assembly of materials, the delivery of products and the availability of services. But transport improvements are too often conceived and provided in relative isolation. Each form of transport must make its own estimate of the situation, its own projections for the future, its own judgments as to how it will share in that future. Public policies of regulation and promotion are diverse, uneven, and uncoordinated." (104)

Quoting further from the transportation conference report, in regard to some of the barriers to effective action:

> "The problems of data collection and collation are particularly acute. Currently, some kinds of data are abundant but are often incompatible and only rarely addressed to questions of importance for comprehensive understanding and planning in industry and government. Reliable statistics on the movement of people and goods by all modes, showing time trends, cause and effect relationships, and by length, nature and elapsed time of trip simply do not exist. There is little accurate cost-accounting by which time costs can be ascertained and analyzed with assurance. The lack of adequate information undermines the basis for intelligent decisions, both in industry and in government." (104)

There are, then, difficulties in the transportation field in general. They are further compounded in the area of airport transportation by the fact that of over 500 reports and studies reviewed in the course of the present research only two were addressed to a comprehensive study of airport transportation.

Such lack of concern may be, in part, attributable to the fact that airport transportation represents only a very small fraction of the total volume of traffic in any metropolitan area. An important question is thereby raised. Should airport transportation be considered part and parcel of the general metropolitan transportation system? Or, is it more properly conceived as an element or extension of the air travel mode because it is an element of every air trip? In the past, it has not been considered clearly as either, but as a little of each. Because of the relatively small volume of traffic represented by airport transportation as compared with total metropolitan traffic, metropolitan governing agencies can hardly consider problems presented by airport transportation as worthy of special attention. On the other hand, the airline industry does not assume responsibility for the local transport of passengers to and from air terminals. It must be asked then, in all candor, whose problem is it?

The problems of airport transportation are aggravated by the increasing number of air travelers, increasing congestion on roads and highways, expanding suburbia, the advent of multi-airport cities, and the construction of new airports farther and farther from the city. All of these conditions point to a worsening of the situation, the effect of which is to mitigate against the prime advantage of air travel, namely speed, or time savings. The situation, even today, is such that, for short-haul trips, the speed advantage of air travel is by no means clear-cut.

Airport transportation is related to many other aspects of the broad field of commercial aviation. For example, one fact to be considered in segregating air traffic in multi-airport cities is the local origin-destination pattern of airport users. Total travel time can be considerably influenced by the local ground travel time; total trip costs can be materially affected by airport transportation costs. The air travel market itself can be influenced when the relative convenience, time, and costs of airport transportation make other travel modes more competitive with air travel. This is especially true for the short-haul market. The design of airports can be affected by the kind of airport transportation which serves them. A factor that should enter the decision as to where to locate a new airport is the relation of the airport to the local origin-destination pattern of airport users. These are but a few examples of the relationships between airport transportation and the problems in commercial aviation.

If steps are to be taken to alleviate problems in airport transportation, it is necessary first to specify the problems in explicit terms and to identify the factors that contribute to the difficulties. Secondly, means must be developed to permit objective evaluation of proposed

solutions, so that those solutions which appear promising can be identified. This study is oriented toward accomplishment of these primary goals. The facts reported should contribute to a better understanding of airport transportation problems to the development of tools which can be instrumental to their resolution.

The results of this study are contained in the report which follows. It is organized into five major parts.

Part I: The Problem

In this part, the characteristics of airport transportation are explicitly identified. Facts concerning airport transportation are superimposed on facts concerning the metropolitan mass transportation of which airport transportation is a part. Salient features in Part I include data on the relation between airport transportation time and total travel time, the growth in air travel volume, airport locations, travel modes of airport users, and the local origins and destinations of airport users. In addition, those characteristics of metropolitan transportation in general which are pertinent to the airport transportation problem are discussed.

Part II: Case Studies

At the outset of the project, it was decided that although we were addressing the airport transportation problem in general, it would be instructive to concentrate special emphasis on a number of different airport(s)-city complexes, in order to come more directly to grips with the problem and to provide specific data in which we might better identify pertinent factors. Accordingly, four locations--New York City, Chicago, San Francisco, and Washington, D. C.--were selected. In Part II, these four case studies are presented to illuminate both the commonalities and the differences in the problems that exist in these quite different situations.

Of particular relevance are results of a survey conducted at Washington National Airport as part of the present study to establish the local origin-destination pattern for users of the airport. General findings of the survey are incorporated in the chapter on Washington, D. C. A separately-bound detailed report of the survey is presented in Appendix B.

Part III: Analysis

Part III identifies those factors which influence the problem for the purpose of isolating parameters which can be used in comparative evaluations of transportation systems and system combinations presently employed or proposed for the movement of people to and from airports. The first section describes our approach and proposed methods of evaluation. The next five chapters explore five major classes of factors which influence airport transportation. In each case, the objective is to establish relevant, objective evaluative parameters.

Part IV: Means for Evaluation of Airport Transportation Systems

In this part, explicit procedures for employing a mathematical model in the evaluation of kinematic factors are described. A computer logic-flow diagram is presented. The data requirements and the evaluative parameters identified in this study are briefly summarized.

Part V: General Characteristics of the Solution

One of the tasks of this study was to describe, on the basis of what we had learned from the entire investigation, what characteristics of systems appeared to hold promise for the alleviation of the airport transportation problem. Part V examines some of the implications of the study results for a number of proposed improvements in airport transportation.

## PART I. THE PROBLEM: AIRPORT-METROPOLITAN TRANSPORTATION

The purpose of this section is to examine the nature of the trips that an airline passenger must make on both ends of a flight--the trip from his local point of origin to the air terminal and the trip from the terminal to his local destination point.

### Chapter 1. Travel To and From Airports

#### Analysis of Trip Time

Speed is considered by the traveling public to be the most significant advantage of air travel over other modes (239, 424, 425). It is appropriate, therefore, to analyze total trip time from its constituent parts to determine the relationship of airport transportation to total trip time.

In intercity travel within the United States, an airline passenger spends, on the average, from 22 to 65% of his total travel time traveling to and from airports. This means that the time savings afforded by high speed air travel are not as impressive as the flight speeds would indicate.

For the purpose of the analysis which yielded the above percentages, total travel time from point of origin to point of destination was conceived as divided into five arbitrary intervals (A, B, C, D, E in Figure I-1.)

FIGURE I-1

Passenger Trip Time Intervals

Time (minutes)


| Time Interval | Begins When: | Ends When: |
|---|---|---|
| A | Passenger leaves home, office, etc. | Passenger enters Airport Terminal 1 |
| B | Passenger enters Airport 1 Terminal | Passenger on aircraft and doors closed |
| C | Passenger on aircraft and doors closed | Aircraft doors open at Airport 2 Terminal |
| D | Aircraft doors open at Airport 2 Terminal | Passenger leaves Airport 2 Terminal |
| E | Passenger leaves Airport 2 Terminal | Passenger arrives at destination |

The analysis to be presented takes its data from the 50 most heavily traveled city-to-city routes in the United States. According to a 1958 survey conducted by the Civil Aeronautics Board and the American Transport Association, 14 of the 50 most heavily-traveled routes between pairs of domestic stations were shorter than 250 air miles in length, 15 were in the range of 250-500 miles, 12 were from 500-1000 miles, and 9 were more than 1000 miles apart (97). The number in each range is roughly proportionate to the total number of passengers in each interval for all flights in 1958, although longer trips are not as well represented.

In Table I-1, pertinent data on current air and ground travel time are summarized for these "top 50" pairs. Ground travel time and distance are calculated between airports and central business districts. The central business district has been chosen as a reference point although, as will be shown later, only 40% or fewer of airline passengers travel between it and the airport. Nonetheless, it is believed that the central business district is an appropriate reference point for this analysis.

The figures in the table are averages for the pairs of cities. For example, in the 0-250 mile range, the average mileage between the airports in question is 178 miles which takes about 53 minutes in actual air time; ground travel distance (between city center and airport in both cities) is about 23 miles, and it takes between 55 to 99 minutes to complete the ground travel to and from the airports.

What does Table I-1 represent in terms of the time intervals defined in Figure I-1? The minutes in Column 2 represent an approximation to Time Interval C. They are underestimates since the data used are for scheduled takeoff and landing and do not take into account (1) surface delays, which may range from one to thirty minutes, or (2) air delays, which may range from five minutes to two hours. Thus, the figures shown are conservative estimates.

The figures in Columns 4(a) and 4(b) represent the shortest and longest interval estimates for the sum of the Time Intervals A, B, D, and E in Figure I-1. This is the sum of the passengers' total travel time exclusive of time in the air. Here again, schedule delays are not taken into account, and it is assumed that no one arrives at the airport more than half an hour before flight time.

TABLE I-1

Summary of Data on Air and Ground Travel Time

(from the 50 most heavily traveled city-to-city routes in the U.S.)

| Between Airport Mileage Range (miles) | Number of Airport Pairs in Each Range | Air Travel Between Airports | | Ground Transportation To and From Airports | | | Percent of Total Trip Time Spent in Ground Travel |
|---|---|---|---|---|---|---|---|
| | | Mean Distance (miles) (1) | Mean Flight Time (minutes) (2) | Mean Road Distance (3) | Mean Travel Time | | |
| | | | | | Maximum (minutes) (4a) | Minimum (minutes) (4b) | |
| 0-250 | 14 | 178 | 53 | 23 | 99 | 55 | 65%-51% |
| 251-500 | 15 | 335 | 83 | 22 | 98 | 54 | 54%-39% |
| 501-1000 | 12 | 709 | 119 | 27 | 116 | 63 | 49%-35% |
| 1001 and over | 9 | 1742 | 246 | 28 | 114 | 68 | 32%-22% |

Explanatory Note: The sources of the above data are as follows:

Col. (1) The minimum air distance between each pair of airports as given by C.A.A. figures, 1956.

Col. (2) The shortest non-stop air time between the airports as determined from the American Aviation Airline Guide, September 1960.

Col. (3) Synthesis of figures given by AAA and the Airline Guide for road distances between airports and city centers for each pair of airports. The figures given are sums of the distances on each end of the trip.

Col. (4a) Maximum Ground Time: Figures published by Airline Guide on allowable time to reach the airport from the city center. It includes time to check baggage.

Col. (4b) Minimum Ground Time: Actual driving time from AAA and Port of New York Authority.

Column 5 shows that, on the average, between 22% and 65% of the passenger's airline trip time is consumed on the ground. For trips of less than 250 miles, this figure is greatest--between 51% and 65%. As trip length increases, percentage of travel time devoted to ground travel decreases to a minimum of 22% for the greater than 1000-mile range. (Figure I-2 presents the air and ground travel time and distance graphically.)

As concrete examples, in Table I-2, the amount of time devoted to between-terminal travel as compared with that for to- and from-terminal travel is shown for three specific trips in the short haul range.

In view of some existing estimates (e. g., figures published by the U. S. Office of Aviation Facilities Planning), air travel in the mileage ranges 0-250 and 251-500 is expected to increase (in relation to the total common carrier market) at a much higher rate than in the longer trip ranges (2). To accomplish this penetration into the short-haul market, three possibilities appear to exist.

(1) The development of aircraft for short-haul operation capable of taking off and landing much closer to city centers than is now possible.

(2) The reduction of present fares to compete with surface common carriers. (This does not reduce travel time, however.)

(3) Development of faster and more efficient means of travel techniques to and from present airports in order to decrease the total travel time.

Based on the data in Table I-1, a reduction of air travel time by 10% for the short-haul ranges saves approximately 5.3 minutes compared to a 5.5 to 9.9 minute saving when ground travel time is reduced by 10%.

FIGURE I-2

RELATION OF FLIGHT TIME AND TRAVEL TIME FOR TRIPS OF DIFFERENT LENGTHS

(DATA TAKEN FROM TABLE I-1)

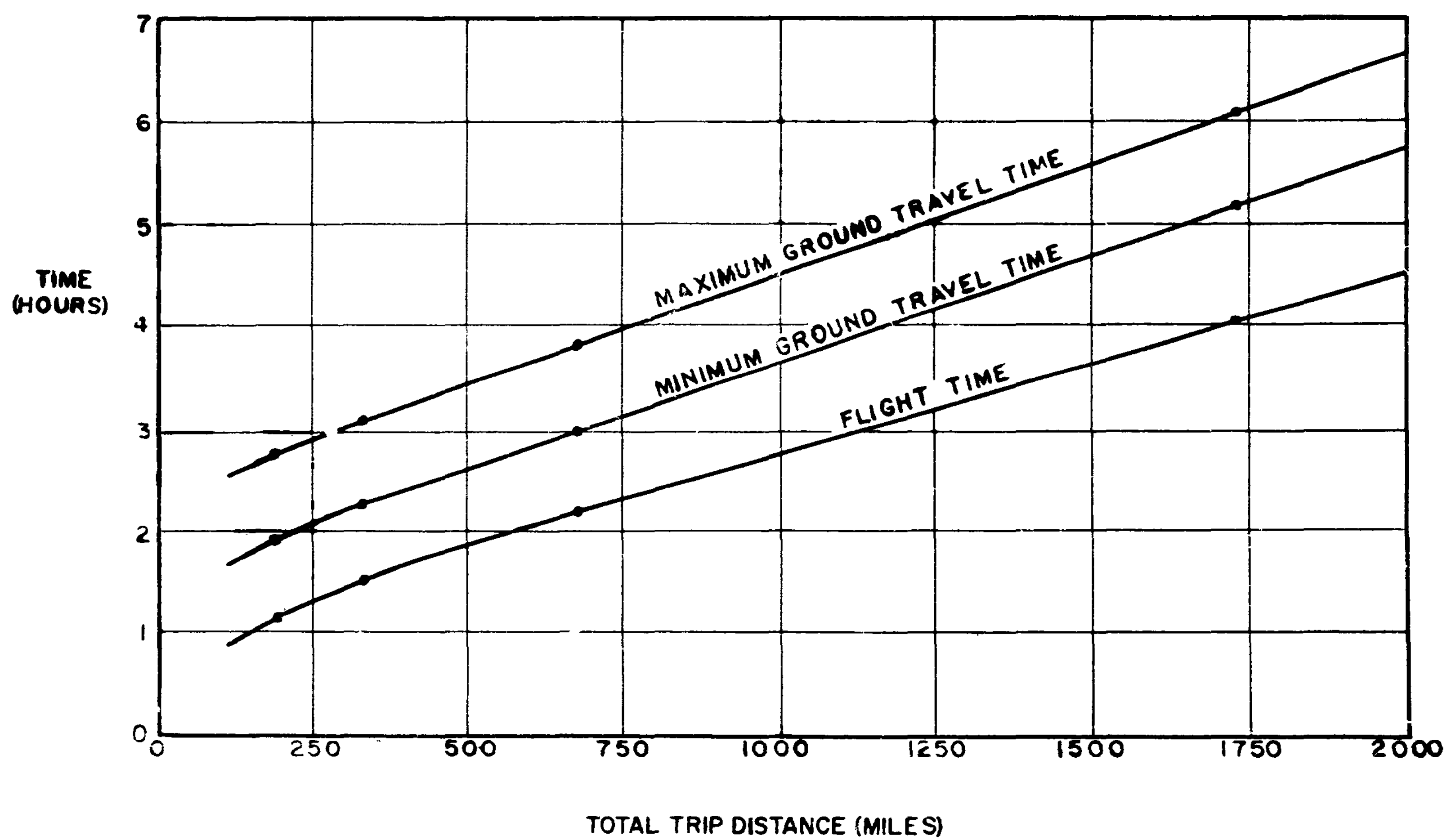


TABLE I-2

Illustrative Examples of the Comparison of Air and Ground Travel Times
for Trips Between the Central Business Districts
of
Three Pairs of Cities in the Short-Haul Range

| TRIP | Flight Travel Time (terminal to terminal) (in minutes) | Travel Time Between Terminals and City Centers (minutes) | Total Trip Time (minutes) |
|---|---|---|---|
| New York - Washington, D. C. | 55 | 42-80 | 97-135 |
| Detroit - Chicago | 53 | 74-125 | 127-178 |
| Boston - New York | 55 | 127-178 | 100-140 |

It becomes obvious that a strong alternative to increasing aircraft speeds to reduce travel time lies in improving the means of ground transport.

Speed is the most frequently mentioned advantage of air travel as reported in the University of Michigan Survey Research Center's national surveys of attitudes toward all travel modes. (239, 424, 425) In the 1955, 1956, and 1957 surveys of all advantages and disadvantages reported the advantage of speed accounted for 45% to 50% of all advantages and disadvantages mentioned. (The next most frequently mentioned advantage or disadvantage--comfortable, good passenger facilities--accounted for only 12.6% of the total.) Because the traveler can not experience speed differentials in typical commercial aircraft, it is probably safe to conclude that it is the time saving aspect of speed and not the experience of speed which is attractive to the public. To the extent, therefore, that ground transportation reduces the time savings afforded by air travel, it can be considered to represent a negative feature to the air traveler.

Whereas we can anticipate with some confidence that air travel time will be further reduced in the future (at least in respect to aircraft speed capabilities), there is little basis for expecting a reduction in ground travel time. In fact, there is reason to predict that ground travel, over-all, will tend to become slower rather than faster--in spite of improvements, in some localities, brought about by airport expressways and helicopters. Reasons for this prediction will be taken up in more detail later, but they include: doubling of passenger volume by 1968; location of airports farther from cities; increased congestion in all forms of ground travel; increased traveling population, and changing characteristics of the burgeoning suburbia. And as there is nothing comparable, among modes of ground travel, to the the technological advances which make possible remarkable increases in speed of air travel, not only the

proportion of total trip time taken up by local ground travel, but the actual ground travel time as well can be expected to rise.

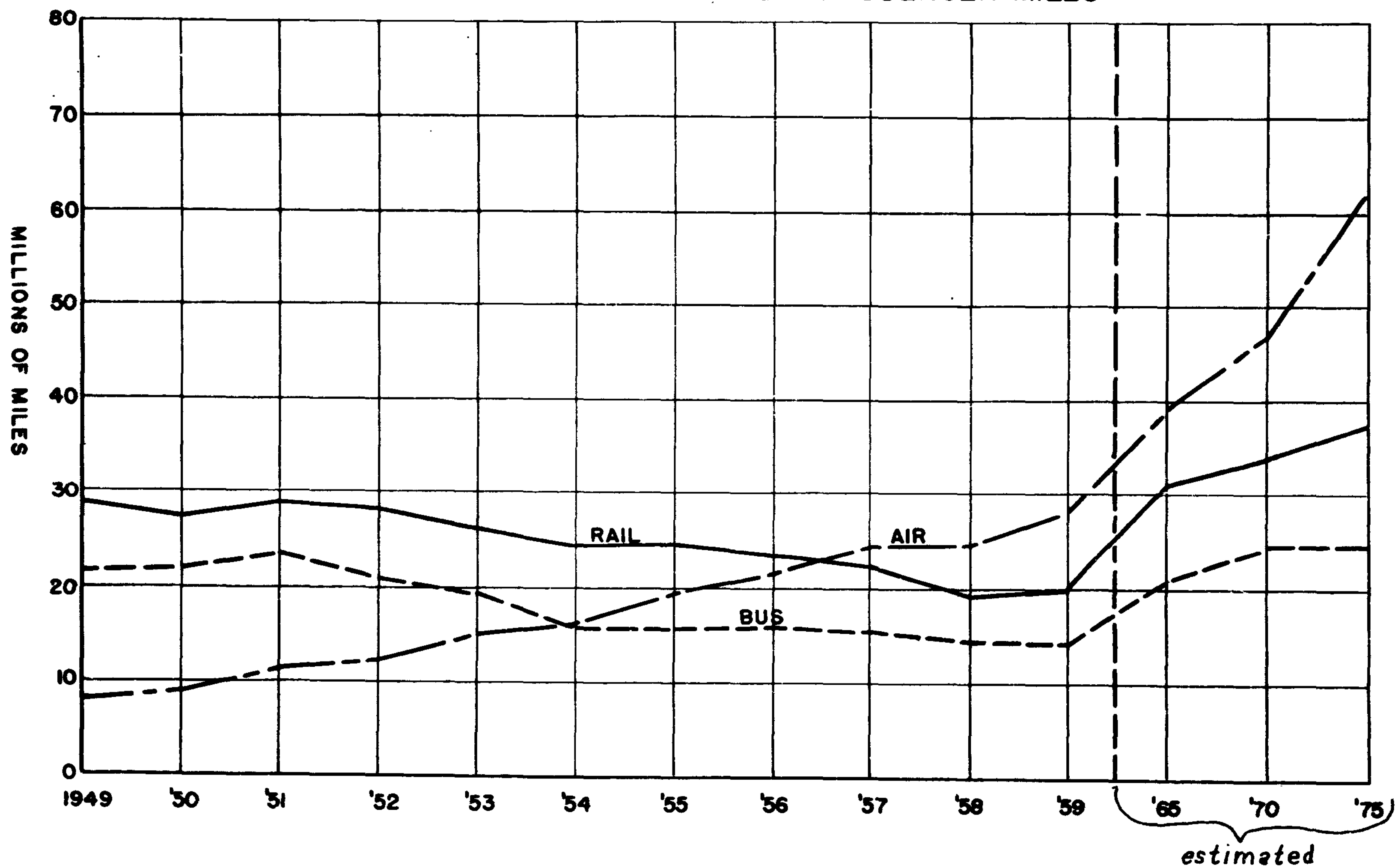
## Growth in Air Travel Volume

The ground travel time problem will be faced by an ever growing number of people. The growth of the airline industry need not be reviewed here except to point to the number of people involved.

Figures I-3, I-4, and I-5 present a brief sketch, in numbers, of air travel volume, past, present, and future. Figure I-3 compares air, rail, and bus common carriers in terms of passenger-miles and shows the steady rise of air travel in contrast to the decline in rail and bus travel. In Figure I-4, the percent of total intercity passenger-miles accounted for by airlines is depicted. The percentage has quadrupled in the last ten years. The number of airline revenue passengers, in the past and projected into the future, is shown in Figure I-5. In the 30 years between 1946 and 1975, an 11-fold increase is estimated which would mean 167 million passengers in 1975. This compares with an estimated 90 million in 1965 and an actual 49 million in 1959.

The basic point is clear. In 1975, the number of airline passengers is estimated to be approximately equal to the total population of the United States in 1955. Each of these travelers is faced with the problem of getting to and from the airports. It is evident that from a national or industrial standpoint the number of passengers demanding airport ground transportation is a significant figure.

FIGURE I-3
INTERCITY COMMON CARRIER PASSENGER-MILES

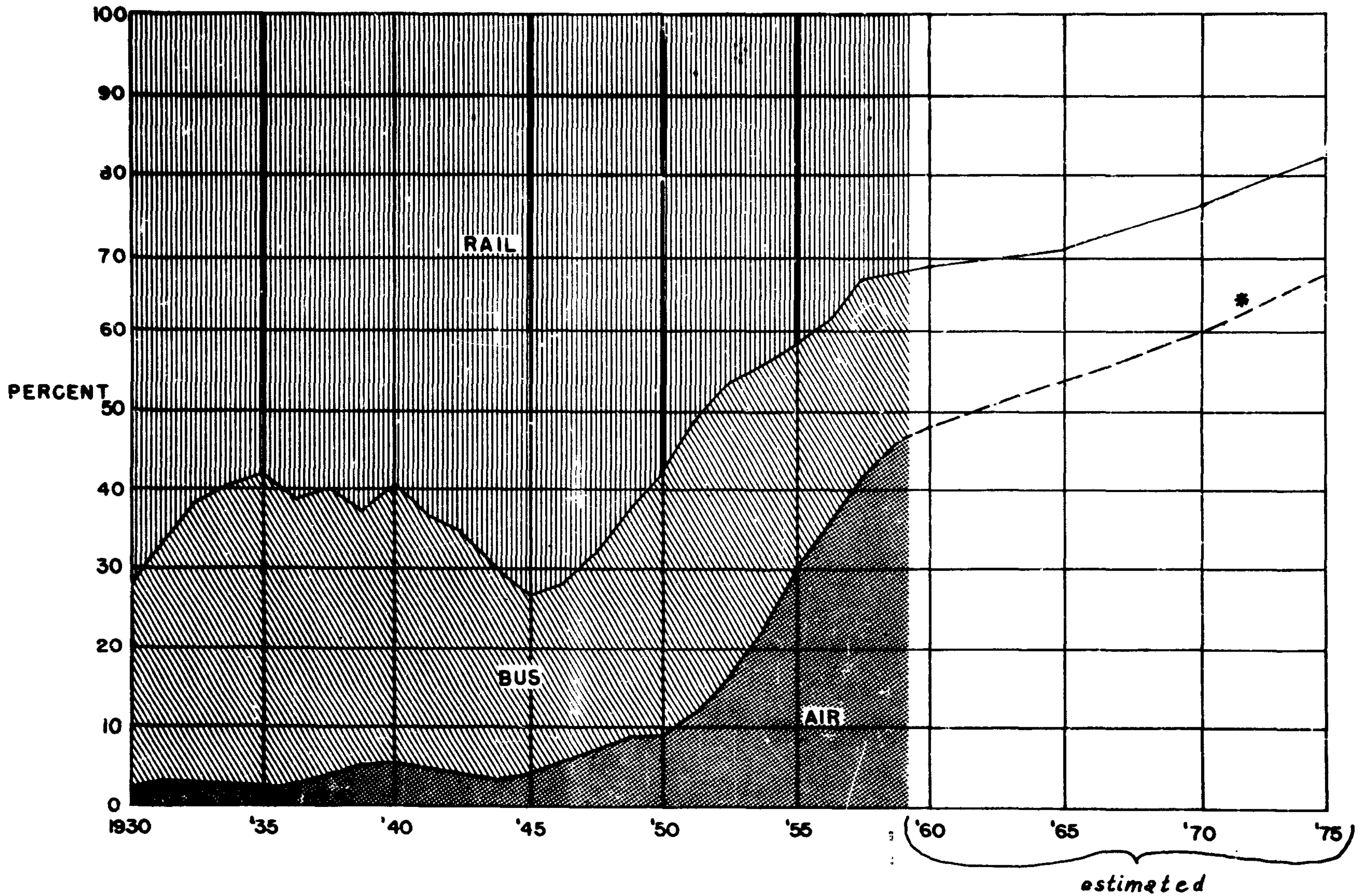



SOURCE: (4, 2)

FIGURE I-4

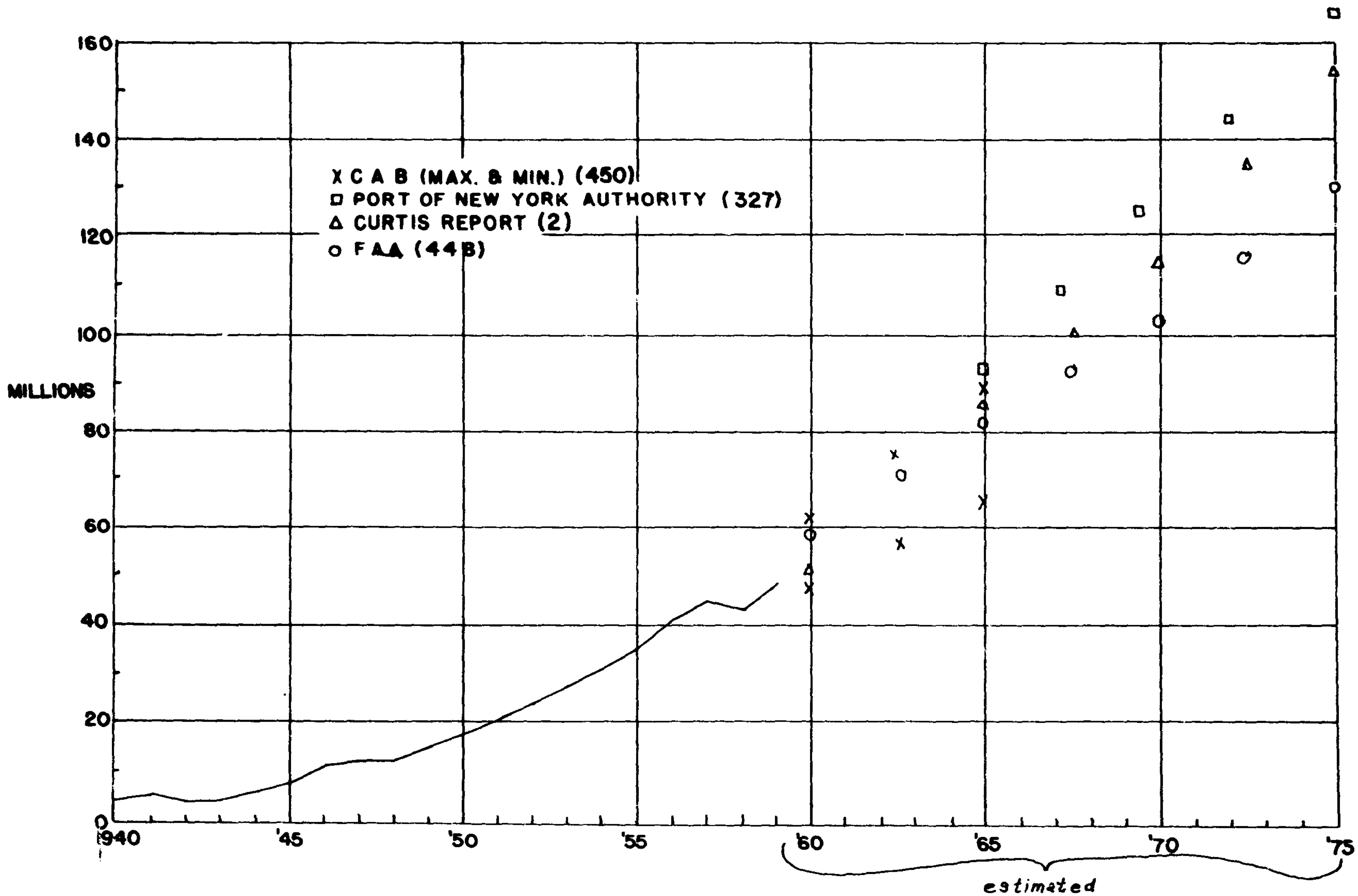
PERCENT OF INTERCITY PASSENGER-MILES BY COMMON CARRIER

*ESTIMATES WERE ADJUSTED FOR TREND OF INCREASED AIR PENETRATION




SOURCE: (2)

FIGURE I - 5
NUMBER OF AIR PASSENGERS



## Airport Locations

Cities are building more airports and they are being built farther and farther from city centers. Distances from city centers to airports of major cities have been presented in Table I-3--they range from 2 to 32 miles. The requirements for more and longer runways, the unavailability of land, and the noise of jets all tend to push airports farther from the city. Suburbia is spilling out around cities for many miles and is distributing the origins and destinations of airport users over vast areas. Even though airports will tend to be located farther from the cities, the suburban encroachment presents the problem of ground traffic congestion not only surrounding the airport, but along the routes to the cities.

All of these factors tend to worsen the airport transportation problem. Distances are increasing, origins and destinations are dispersing, and congestion in the area surrounding the airport and the airport-city routes is increasing. Again, there is nothing in this pattern which tends to favor the improvement of ground travel time. In fact, the increasing number of multi-airport cities creates the additional problem of airport to airport transportation for through-passengers who heretofore had no need for local transportation.

## Modes of Airport Travel

An important element in the basic problem is the means by which present-day airport users travel to and from the airport. Where evidence is available, the pattern is consistent, which gives some justification for making the inference that the pattern is relatively general.

TABLE I-3

Distances and Times From City Centers to Airports

For Large Hubs in the United States

| | | Approximate Mileage From Airport to City Center | Ground Travel Time Range |
|---|---|---|---|
| Atlanta | | 9 | 20-50 |
| Boston | | 2 | 15-30 |
| Buffalo | | 8 | 30-50 |
| Chicago: | Midway | 11 | 36-75 |
| | O'Hare | 22 | 42-80 |
| Cincinnati | | 12 | 35-50 |
| Cleveland | | 12 | 30-35 |
| Dallas | | 7 | 20-40 |
| Denver | | 6 | 40-55 |
| Detroit: | Metro. | 18 | 35-50 |
| | Wl. Run | 32 | 45-50 |
| Houston | | 10 | 35-50 |
| Kansas City | | 2 | 10-15 |
| Los Angeles | | 14 | 40-60 |
| Miami | | 7 | 35-45 |
| Minneapolis | | 9 | 25-30 |
| New Orleans | | 12 | 50-60 |
| New York: | Idlew. | 15 | 31-60 |
| | LaG. | 10 | 21-50 |
| | Newk. | 12 | 21-45 |
| Philadelphia | | 8 | 21-35 |
| Pittsburgh | | 17 | 27-60 |
| St. Louis | | 14 | 35-60 |
| San Francisco | | 13 | 35-60 |
| Seattle-Tacoma | | 13 | 30-60 |
| Tampa-St. Pet. | | 6 | 15-40 |
| Washington, D. C. | | 4 | 14-30 |
| MEDIAN | | 11 miles | 30-50 minutes |

Source: (306)

Private automobile, taxi, and limousine are used at almost all major airports in the United States and foreign countries. At approximately 80% of the 26 United States airports and 80% of the 24 foreign airports surveyed, public buses operate (362). Passenger-carrying rail facilities reached only one airport in the United States (Boston), and six in foreign countries. At the present time only three cities--Chicago, Los Angeles, and New York--have scheduled helicopter service.

The data on travel modes are sketchy, not comparable from city to city, and--for the most part--of unknown accuracy and reliability. The available sources have been combed for travel mode data and the results are tabulated in Tables I-4 and I-5. The number of accompanying explanatory notes attest to variegation and non-comparability of the available data. Nonetheless, a general pattern can be discerned in these data which is depicted in Figure I-6.

In the United States, the private automobile appears to account for from 37% to 74% of the airline passengers. Taxis account for from 12% to 41%, and limousines from 18% to 38%.[1] Public buses carry no more than 4% of passengers and in some instances none at all. Other modes carry negligible percentages (up to 1959). These data produce a pattern such as is shown in Figure I-6.

This pattern shows the dominance of the private automobile. Taxi and limousine account for most of the remainder. Public bus or rail transit play no significant role and, although on the increase, the helicopter still carries fewer than 5% of the passengers.

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[1] In the survey which yielded the Chicago data in Table I-4, it was also determined that between 61% and 79% of limousine passengers traveled in some other vehicle to get to the limousine or after leaving it.

TABLE I-4

Summary of Travel Mode Data at 10 U.S. Airports

| Airport | Date | Source | Notes | Percent of Passengers Travelling by Each Mode | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Private Auto | Taxi | Limo Airport Bus | Public Bus | Rapid Transit | Rail-road | Rental Car | Heli-copter | Others |
| Chicago | 1955 | 1 | | 40 | 34 | 21 | -- | -- | -- | -- | -- | 5 |
| Cleveland | 1957 | 2 | b | 54 | 14 | 27 | 1 | -- | -- | 3 | -- | 1 |
| Dallas | 1956 | 3 | | 55 | 22 | 20 | 2 | -- | -- | -- | -- | 1 |
| Houston | 1959 | 3 | a | 74 | ←26→ | | -- | -- | -- | -- | -- | -- |
| Minneapolis, St. Paul | 1955 | 3 | b | 59 | 23 | 18 | 0 | -- | -- | -- | -- | -- |
| N.Y. International | 1956 | 3 | c | 42 | 26 | 31 | 1 | -- | -- | -- | d | -- |
| N.Y. LaGuardia | 1956 | 3 | b | 37 | 41 | 20 | 2 | -- | -- | -- | d | -- |
| N.Y. Newark | 1956 | 3 | b | 46 | 12 | 38 | 4 | -- | -- | -- | d | -- |
| San Francisco | 1958 | 4 | b | 78 | 6 | ←16→ | | -- | -- | -- | -- | -- |
| Washington, D. C. | 1960 | 5 | | 31 | 43 | 18 | 1 | -- | -- | 4 | -- | 3 |

Notes:

Sources:
1) 80
2) 149
3) 383
4) 145
5) Appendix B of this report.

a) Estimated
b) Enplaning Passengers Only
c) Domestic Enplaning Passengers Only
d) Fewer than one percent

TABLE I-5

Summary of Travel Mode Data at 10 Foreign Airports (362)

| Airport | Notes | Percent of Passengers Travelling by Each Mode | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Private Auto | Taxi | Limo Airport Bus | Public Bus | Rapid Transit | Rail-road | Rental Car | Heli-copter | Others |
| Amsterdam | e, a | -- | -- | 40-50 | -- | -- | -- | -- | -- | -- |
| Brussels | f | -- | -- | -- | -- | -- | 30 | -- | d | -- |
| Frankfurt | | ←48→ | | ←49→ | | | | | | |
| Hong Kong | g | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Johannesburg | a | ←30→ | | 70 | -- | -- | -- | -- | -- | -- |
| London Central-North | b | 41 | 5 | 50 | 4 | -- | -- | -- | -- | -- |
| London-Gatwick | b | 24 | 1 | 6 | 0 | -- | 69 | -- | -- | -- |
| Paris-LeBourget | h | 12 | 64 | -- | ←22→ | | | -- | -- | 2 |
| Paris-Orly | h | 14 | 63 | -- | ←20→ | | | -- | -- | 3 |
| Sidney | a | 25 | -- | 75 | -- | -- | -- | -- | -- | -- |

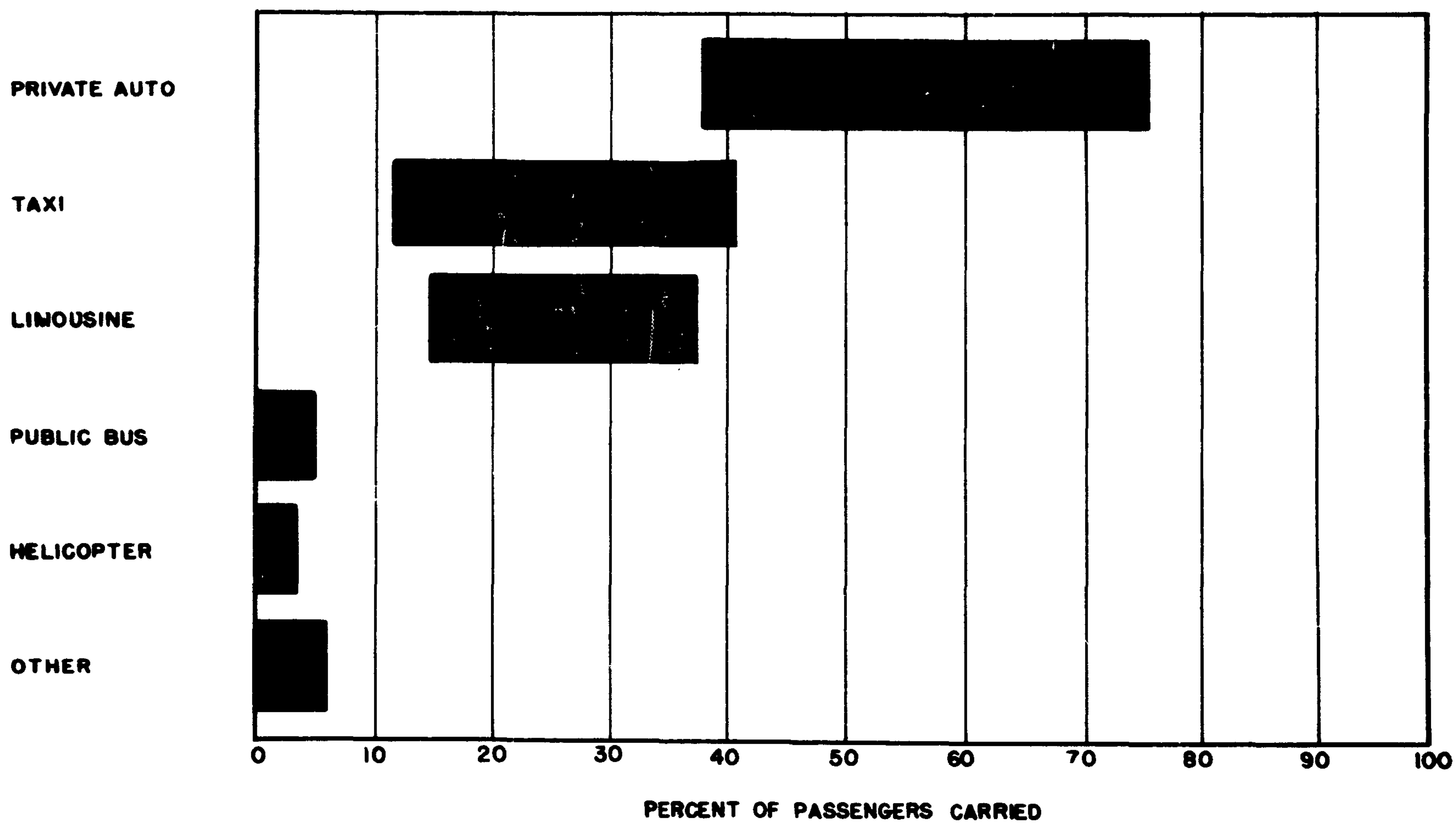
Notes:

a) Estimated
b) Enplaning Passengers Only
c) Domestic Enplaning Passengers Only
d) Fewer than one percent
e) Estimated 50-55% Use Auto, Taxi and Public Bus
f) Estimated for Those Passengers Having Origin or Destination in City of Brussels
g) Majority Arrive and Depart by Auto and Taxi
h) Travel Mode to and from Invalides In-Town Airline Terminal

FIGURE I- 6

PATTERN OF AIRPORT LOCAL TRANSPORTATION MODES

(RANGE OF PERCENT OF PASSENGERS CARRIED SUMMARIZED FROM ALL SOURCES OF DATA AVAILABLE)



The data in Tables I-4 and I-5 refer to airline passengers only and do not include the travel mode of airport employees and visitors, who together account for somewhere near 50% of all daily airport users. No information is available that would indicate that the largest part of the employee-visitor category travels by anything but private automobile.

The evidence appears to support the conclusion that not fewer than 75% of airport users travel to and from the airport in unscheduled, rubber-tired vehicles of a capacity equal to six or fewer.

## Airport Users

The total group of people who use an airport is composed of four sub-groups which may be defined as follows.

Passengers: People at the airport who are originating or terminating an air trip. Included are both commercial and private passengers. Not included are through passengers who do not leave the airport between flights.

Employees: People whose normal place of work is the airport. Included are flight crews and stewardesses who arrive at or depart the airport other than by air.

Visitors: People who are:

(1) taking a passenger to or meeting a passenger at the airport;

(2) sightseeing;

(3) using airport concessions;

(4) making reservations or purchasing tickets;

(5) serving as special purpose personnel (e. g., detectives, photographers, etc.).

Service Suppliers: People who make deliveries or provide services at the airport but whose place of employment is not the airport.

The relative percentages of the different types of airport users vary from airport to airport and are difficult to ascertain very precisely. One study of terminal populations which included Chicago-Midway along with airports in Dallas, Ft. Worth, Nashville, and New York showed the following percentages (185).

TABLE I-6

Components of Daily Airport Users Population

| | |
|---|---|
| Air passengers (originating and terminating flights) | 33 - 56% |
| Employees | 11 - 16% |
| Casual visitors (including sightseers and persons accompanying or meeting air passengers) | 31 - 42% |

No figures were given for service suppliers which we have some reason to believe would be in the neighborhood of 3-7% of the total. Based on the above percentages, which are consistent with a number of other sources of partial data and estimates, it appears that air passengers constitute approximately 50% of the total daily airport population. The percent of employees is likely to vary considerably depending upon whether or not one or more major airlines have maintenance facilities or administrative offices located at the airport. Another source of variation is the happenstance that on the airport grounds may be office facilities which are used for non-airport related purposes; e. g., Building T-7 at Washington National Airport houses about 4,000 military personnel who use parts of the airport road system to come to and go from work. For these reasons, the actual percentages need to be

determined for each airport, but the present purpose is to develop a picture of the general situation obtaining.

## Origins and Destinations of Airport Users

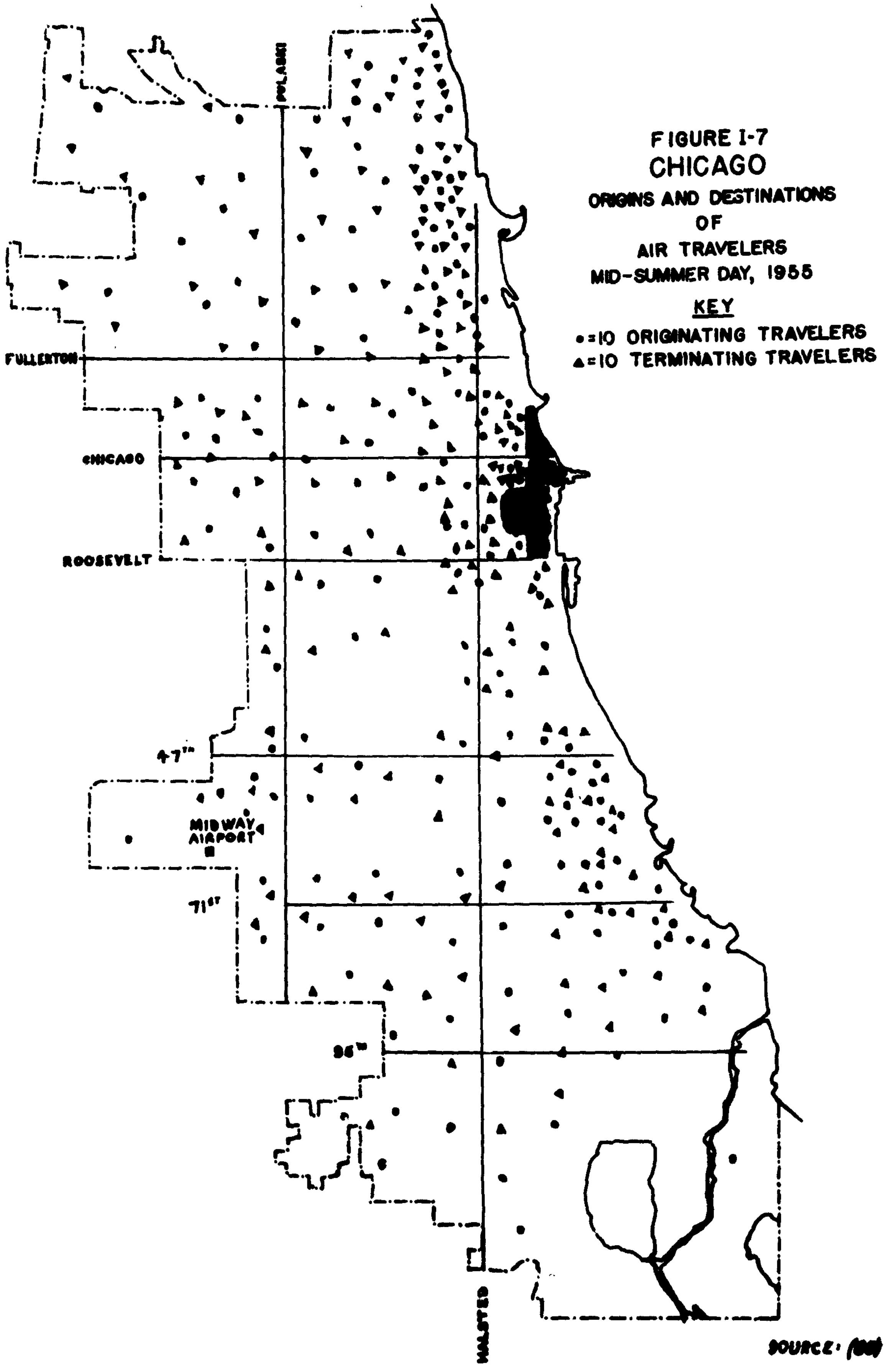
Knowledge of the local origins and destinations of airport users is perhaps the most elementary and necessary information required to make any serious inquiry into the comparative merits of transportation systems designed to transport them, and yet, information of this type is almost totally lacking. To compare and evaluate systems at any particular airport adequately, it would be necessary to establish such information to a fairly high degree of precision (see Part IV). This fact appears elementary when stated, but that it deserves emphasis is underlined by the absence of such data.

Partial data have been found for four major cities--New York, San Francisco, Cleveland, and Chicago--and a survey was conducted in the course of this study to obtain local origin-destination data for Washington, D. C. The data for New York City and San Francisco are analyzed in terms of boroughs or counties which are geographically too large to permit more than an extremely gross picture of local origins and destinations. The data on Cleveland, Chicago, and Washington, D. C. are analyzed by much smaller geographic units and give a much more accurate and detailed picture of local origins and destinations. These data are presented in Figures I-7, I-8, and I-9. (A more complete analysis of the Washington, D. C. data appears in Part II and Appendix B.)

A number of consistencies are noted among these three maps.

(1) Approximately 40% of the passengers originate or terminate in the central business district. (This is estimated to be approximately 20% of the total daily airport user population.)

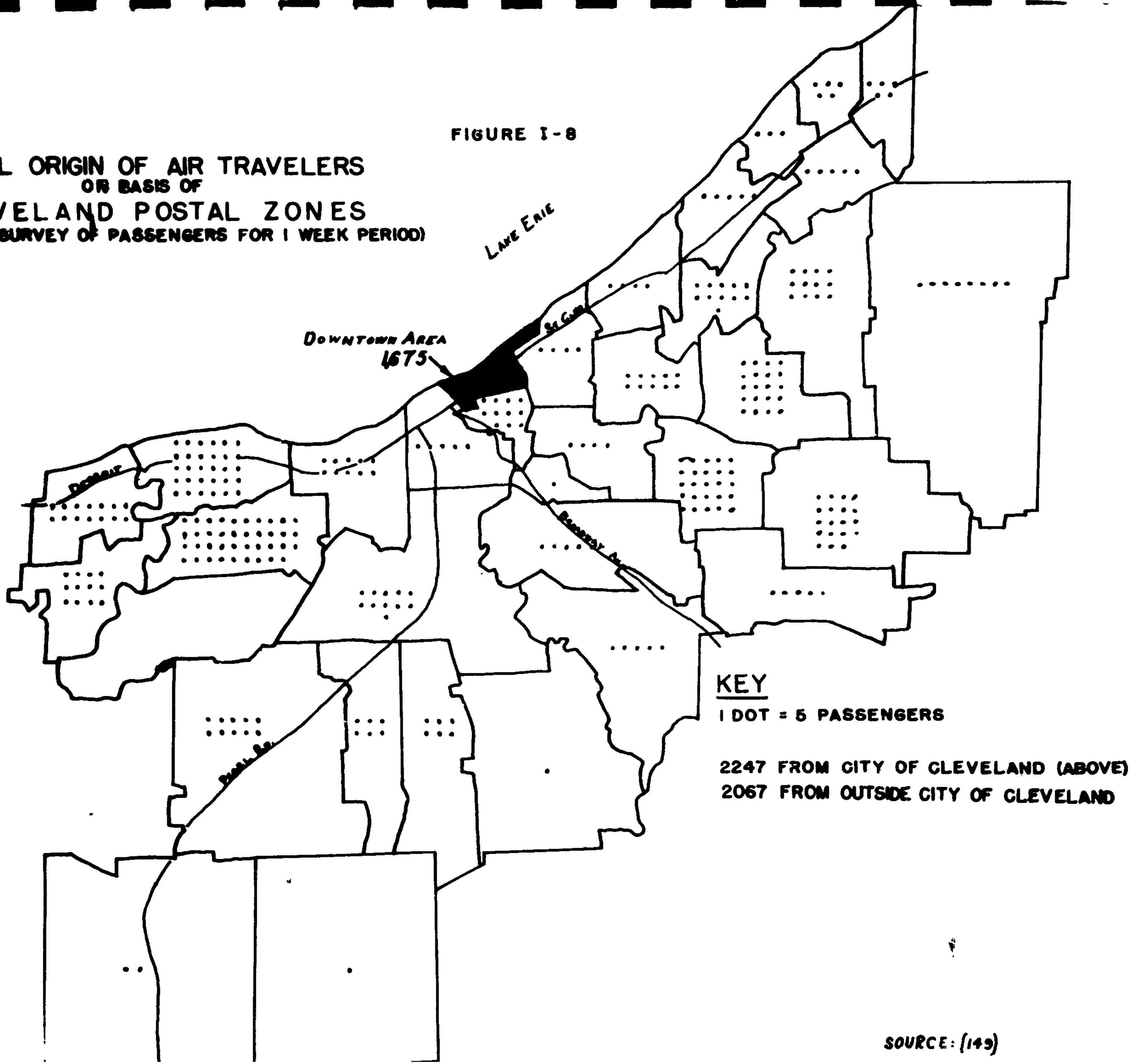
FIGURE I-7
CHICAGO
ORIGINS AND DESTINATIONS
OF
AIR TRAVELERS
MID-SUMMER DAY, 1955




SOURCE: [illegible]

FIGURE I-8

LOCAL ORIGIN OF AIR TRAVELERS
ON BASIS OF
CLEVELAND POSTAL ZONES
(FROM SURVEY OF PASSENGERS FOR 1 WEEK PERIOD)

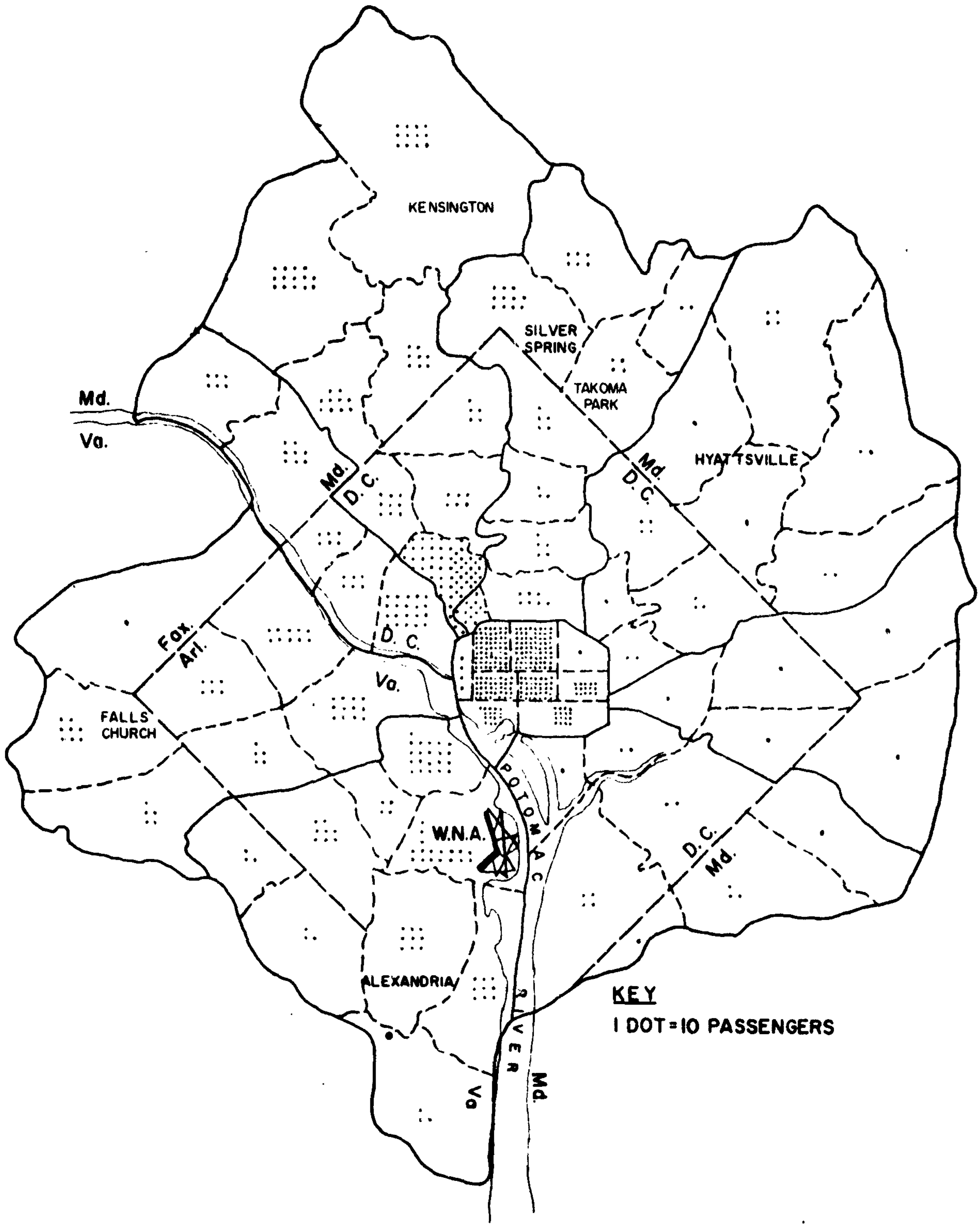



SOURCE: (149)

FIGURE I-9

# LOCAL ORIGINS & DESTINATIONS OF PASSENGERS AT W.N.A.

(FOR AN AVERAGE WEEKDAY DURING WEEK OF 5—11 DEC. 1960)




**NOTE**: FIGURES GIVEN ARE ESTIMATES BASED ON AN 11% SAMPLE FOR A ONE WEEK PERIOD. SEE APPENDIX B FOR DETAILS.

(2) The majority of origins and destinations are widely dispersed over the entire area with very few high concentrations other than in the central business district.

(3) A few areas exist in each city in which almost no origins and destinations occur.

(4) Low-density residential areas account for as many origin-destinations as the high-density business district, or even more.

(5) The maps shown are for a 24-hour day. In terms of volume per hour, the transportation demand is extremely low in the total area with the possible exception of the central business district.

These highly dispersed and diluted concentrations of origins and destinations probably account, in large measure, for the popularity of the private automobile as a means of traveling to and from the airport. For a large proportion of the passenger population, the use of any other mode, currently available, would likely involve some or all of the unfavorable circumstances of high costs, change of modes, lengthy waiting times, inconveniences with baggage, and long travel times. The implications of this general origin-destination pattern for airport transportation are manifold, as shall be seen repeatedly throughout this report.

## Chapter 2. Metropolitan Transportation Problems

The airport local transportation problem can be understood only in the context of the total metropolitan transportation problem of which it is a part. Airport traffic generally accounts for considerably less than 1% of the total daily traffic in a metropolitan area. For this reason, it is the characteristics of metropolitan transportation which define the airport transportation problem and which will determine some of the requirements for its solution. As part of the definition of the problem, therefore, we must examine, in some detail, metropolitan transportation.

### Population Explosion

The metropolitan transportation problem in general may be defined as the congestion and the resultant creeping strangulation which are endemic to the movement of large numbers of people into, out of, and within our urban areas. The dramatic characteristics in population growth and urbanization (see Table I-7) are pointed up in such commonplace phrases as "exploding metropolis" and "population explosion".

"In 1950, there were 32 metropolitan areas with a population of more than one-half million people. Within the next generation the number is expected to double to approximately 65. The population gain of the United States in the next 20 years is estimated at about 75 million people, and the net effect is expected to be that virtually all of the 75 million people will live in metropolitan areas". (228)

TABLE I-7

Population Explosion

| | |
|---|---|
| 1940 .................. | 132,000,000 |
| 1950 .................. | 151,000,000 |
| 1960 (Est.)............. | 179,000,000 |
| 1970 (Est.)............. | 209,000,000 |
| 2060 (Est.)............. | 600,000,000 |

- 80% of the increase taking place in urban areas
- 40% of the increase taking place in 25 largest cities
- 60% of population living on 1% of land

## Suburban Growth

Superimposed upon this metropolitan growth is the growth of coalesced metropolitan areas--the megalopolises. There are at present seven of these "linear cities": Seattle-Tacoma, San Francisco Bay, Los Angeles-San Diego, Chicago-Milwaukee-Northern Indiana, Detroit-Toledo, Cleveland-Pittsburgh, and the name-defying sprawl that stretches from Boston to Norfolk, Virginia, along the Atlantic seaboard. In this last megalopolis, thirty million people, one-sixth of the nation's population, occupy one twenty-fifth of the country's land surface. Yet the forecasters already are remarking the probability that within twenty

years this megalopolis will take second place behind the inevitable merging of the three mid-western megalopolises into one. There is as much wisdom as waggishness in the observation that the United States of America is soon to become the United Cities of America.

A significant feature of metropolitan--and megalopolitan--growth today is its strong tendency to sprawl. Due primarily to the automobile, cities grow out, not up, as formerly. "The automobile and truck have engendered mass decentralization of homes, jobs, and shops...as a result, new homes, plants, and shopping centers have sprouted almost helter-skelter throughout the inner and middle suburban belt" (446).

In this helter-skelter sprawl one-family dwellings are the rule, and they are far from mass transit termini. There are no mass origins for economical transit service (230).

Two processes are concurrent in the development of American metropolises today: (1) growth, and (2) fragmentation. The magnitude of the growth process in terms of population is evident from the foregoing. Fragmentation, the second process, involves the structural characteristics of the growth process. These two processes create the crucial dilemma faced, not only by airport transportation, but, indeed, by all of mass transportation. The size of the area in which there is a demand for transportation increases, but the density of the population per area decreases. As the area size increases and the density of the demand--both per time interval and per area--decreases, the operational and economic feasibility of mass transit, as it is known today, becomes less and less likely. To date, therefore, the processes of growth and fragmentation have manifested themselves in the transportation sphere by inordinate increases in the number of automobiles--a 100% increase between 1946 and 1959. But

there is no early end foreseen for the population rise and there is no way for highway building to keep pace with the present rate of increase in automobile registrations. Thus, automobiles--at least in the form we now know them--can not continue to provide the transportation advantages to which their rapid proliferation since the turn of the century must be attributed.

The forms of the basic dilemma which confronts urban transportation in the near future can be described, therefore, as:

(1) Increasing areas with decreasing densities render known means of mass transit unfeasible, both economically and operationally.

(2) It is not possible to provide the streets, highways, and parking facilities for the number of automobiles that would be on our roads if the trend of the past few years continues for long.

It is this dilemma that must be resolved if there is to be a solution to the urban transportation problem.

Fragmentation, or suburbanization, is a critical factor influencing the whole metropolitan mass transportation problem, likewise the subsidiary airport-city transportation problem. To view it in operation, we shall choose the Chicago metropolitan area as an example.[1]

Historically, urban growth in Chicago falls into three eras (446):

(1) The water era--the city is a trading center and farm product processing center, without suburbs.

(2) The rail era--the city has industrial suburbs.

(3) The automobile era--the city has dormitory suburbs.

---

[1] "...the Chicago area offers perhaps the most perfect example among 'millionaire' metropolitan areas in the United States of an urban pattern which has developed in response to the rules of the economics of location and transportation governing in the railroad era." (446)

This tri-partite division of a city's growth history is applicable to four out of the five metropolises in the United States which have an (estimated) population in 1960 of 2 million or more. In Los Angeles, the one exception, the growth structure is primarily the product of its automobile era.

A brief study of a map of Chicago's growth pattern in terms of historical periods points out three specific conclusions, applicable also to many other great metropolitan areas.

(1) The over-all pattern of growth presents a picture of a hand with many fingers.

(2) The over-all pattern is the product of the railroad era, appearing in embryo with the coming of the first canals and railroads in the 1840's.

(3) The automobile era has webbed the fingers close to their bases and filled out between the joints, but the original pattern is still discernible and difficult to alter.[1]

A fourth, and more general, conclusion is that at least until the 1950's city growth followed the available transportation channels. Suburbanization, like civilization, has followed the rails.

"Until 1950, all commuter communities were dependent on rail transportation. No suburban extension had taken root along any radial highway separate from railway lines." (302)

During the 1950's, two developments of the greatest importance to the transportation picture appeared in the process of suburbanization.

---

[1] "It takes a tremendous thrust of energy, analogous to the launching of a satellite, to break away from the mass of an old city to start a new pattern of urban development. Perhaps only governments can do this, as in the case of the British new towns." (76)

The first of these was the emergence of automobile communities. In 1950 the metropolitan area of northeastern Illinois had 102 towns with a population of 2,500 or more. All were located on rail lines. By 1960, about 36 new towns in the area reached the 2,500 mark. At least six of them were not on rail lines. One entire industrial district, Elk Grove, had no rail connections.[1] Especially noteworthy is the fact that this new growth was independent not only of rail lines but even of highway arterials. It was following a new principle--the availability of large parcels of cheap land outside the constraints of zoning ordinances.

The other development was a large-scale industrial and commercial decentralization. Eleven hundred new firms located in the suburbs of Chicago between 1945 and 1959.

"Industrial decentralization stepped up after 1920. Chicago's share of the Northeastern Illinois Metropolitan Area manufacturing employment fell from 84% in 1920 to 81% in 1940 and 72% in 1957. . . By 1940, Chicago had 343,900 production workers and the suburbs, 78,800 . . . By 1957, there were about 225,000 suburban manufacturing workers to Chicago's 831,000 workers." (302, pp. 20-21)

At least three conclusions based on the nature of metropolitan fragmentation during the 1950's should be drawn here, for they have an effect upon the planning of transportation.

---

[1] Figures from the Northeastern Illinois Metropolitan Area Planning Commission.

(1) Concentrations of suburban populations are becoming increasingly dilute.[1]

(2) Crosstown routing for new transportation facilities is the need of the day, and the old hub-and-spoke city transportation pattern will come to look more and more like a spider web.

(3) Metropolitan growth has become less dependent on established lines of communication.

To extend these conclusions further, deciding the optimum location of new transit facilities has, during the 1950's, become vastly more difficult; mass origins for fixed transit facilities are infinitely harder to find; projecting a transportation system for a metropolitan area has added a whole new dimension.

Earlier in this chapter we saw, in brief, the magnitude of the population explosion on a national scale. No less impressive are the figures on the population growth of the suburbs. According to Donald J. Bogue (51), a reversal occurred around 1920, such that thereafter the suburban rings[2] around cities have grown faster than the cities themselves. This phenomenon has become accelerated. Between 1940 and 1950, the population growth in the rings was 2 1/2 times the growth in the cities they surround, whereas since 1950 growth in the rings has increased 6 times faster than in the central cities. The percentage increase between 1950 and 1956 in the total United States population was 9.8%, in the central cities 4.7%, and in the metropolitan rings 29.3%.

---

[1] In the new automobile communities of the Chicago area, the land allotment per capita is at three to four times previously existing levels. Suburban developed land acreage more than doubled between 1940 and 1959 (302).

[2] Rings are those portions of the standard metropolitan areas which lie outside the city limits.

Approximately 70% of the total United States population increase since 1950 has been absorbed in the suburban rings.

Increased Traveling

"If we were to single out the most notable physical characteristic that distinguishes the United States from other countries of the world, it would certainly be the degree of the nation's mobility. The big difference is our ability to move at will from one place to another." (310)

Some reasons for this mobility go back to a colonial past. Others, in their origin, are twentieth century. Here are some of the most important:

(1) The existence of a frontier.

(2) Growth of metropolitan Meccas of culture and trade.

(3) Shortening of the working day and the working week.

(4) Progressively higher income levels.

(5) The institution of paid vacations.

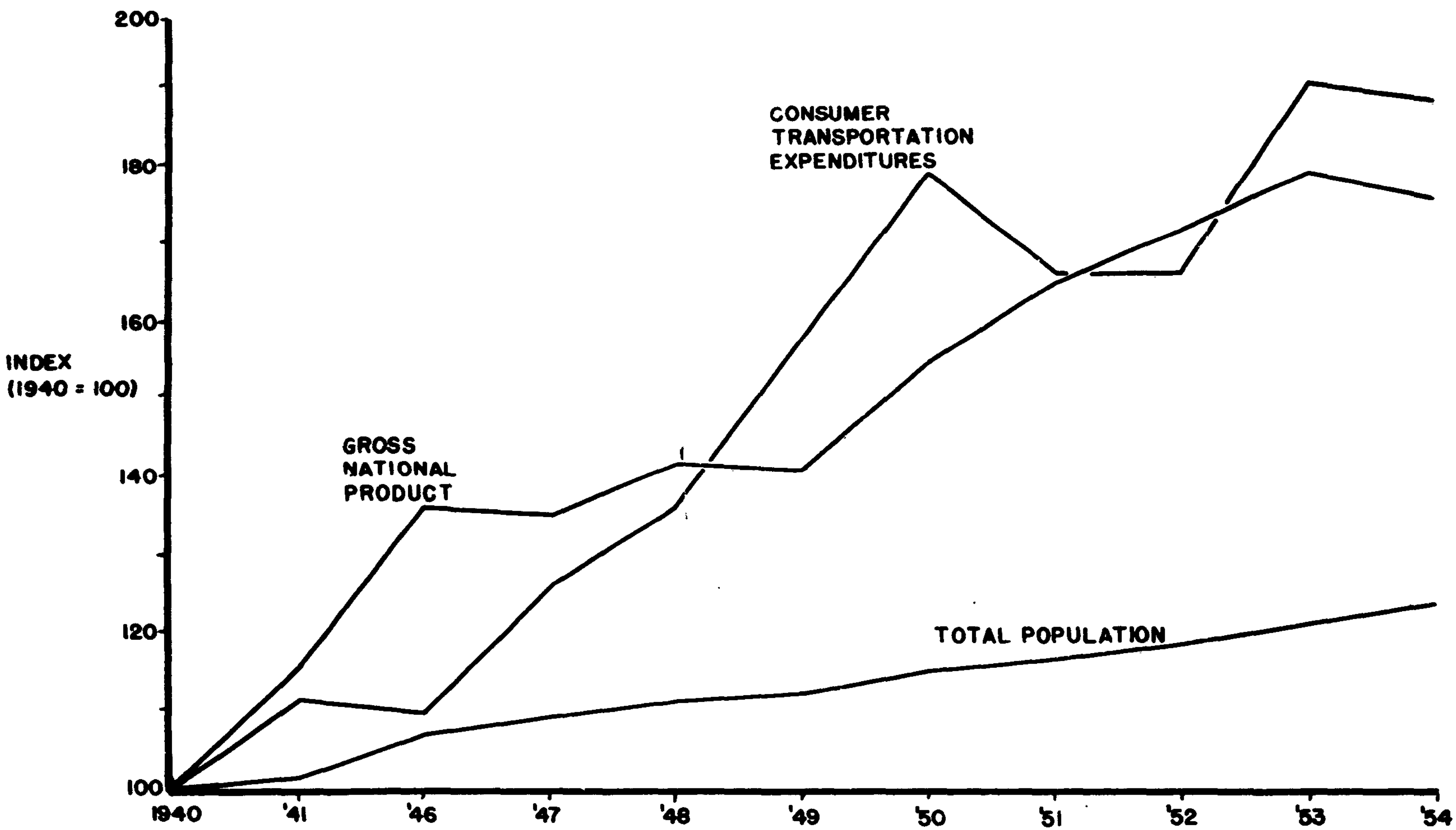
(6) Technological advances in modes of travel.

(7) American middle class origins.

The American's urge to travel and his willingness to pay to do it are illustrated by Figure I-10, which shows transportation trends in their relation to economic growth from 1940 through 1954 (omitting the war years 1942 through 1945). (309) The growth in consumer transportation expenditures exceeds that of the population and the gross national product.

FIGURE I - 10

INDEX OF TRANSPORTATION TRENDS IN RELATION TO ECONOMIC GROWTH




SOURCE: (309)

## Emphasis on the Automobile

Since the end of World War II, motor vehicle registrations in the United States have more than doubled. The United States Bureau of Public Roads provides the data presented in Figure I-11 which show registrations for private automobiles and the total number of motor vehicles since 1899. By 1975 there may well be more than 100 million registered vehicles for 220 million Americans. Almost every other American will have a car (41).

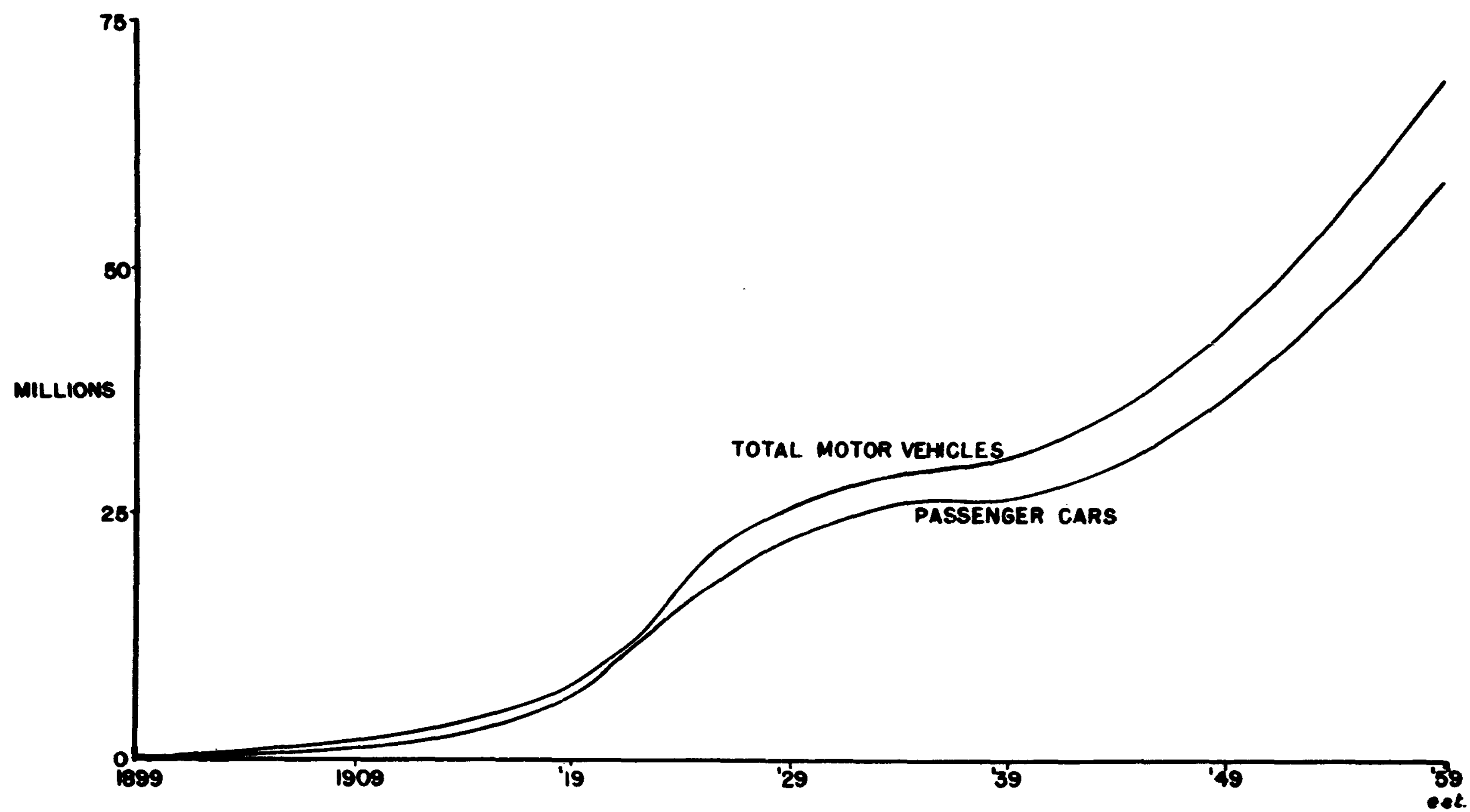
This automotive proliferation may appear more graphic when we consider what is happening in a single metropolitan area, Los Angeles, in which it is perhaps most dramatic. Here, the annual rate of rise in registrations is 35,000. If we estimate the average bumper to bumper length of a motor vehicle to be 20.3 feet, we have in Los Angeles 134.5 miles of newly registered vehicles each year. Considering that Los Angeles is now getting about 6 miles of new 6-lane freeways each year, we see that here the problem of road-room for the automobile will soon become acute (41).

In our larger metropolitan centers people are showing a marked preference for the automobile as a means for making trips within the city. In 15 of the country's 25 largest cities, 60% or more riders use automobiles to travel to the central business district on an average weekday. In 8 of these cities the percentage exceeds 70%.

This preference for the automobile is apparent when we consider travel expenditures in the United States. Ninety-five percent of what Americans spend for moving around is spent on travel in motor vehicles. "They spend more for automobile transportation than... for doctors,

FIGURE I - 11

MOTOR VEHICLE REGISTRATION IN UNITED STATES
(PRIVATELY OWNED VEHICLES)




SOURCE: (24)

religion, charities, telephones, radio, television, furniture, electricity, gas, books, magazines, and newspapers." (310, p. 4) By way of contrast, "Consumers spend more money for flowers, seeds, and potted plants than for all travel by railroad, intercity and commutation combined." In a recent study, Owen (1959) estimates that in the next 15 years we will be spending a trillion dollars for motor transport in the United States.

It is a matter of some complaint among mass transit advocates that the traffic and transportation programs of our cities favor the motorist.[1]

---

[1] Hollis Limprecht, in the World-Herald (447 ), points out that transit companies complain that they are victimized by politicians anxious for votes in the following ways:

(1) Through traffic controls which bring more private cars to the central business district to compete with and slow down public transportation.
  a. Rush-hour parking bans.
  b. One-way streets.
  c. No-turn intersections.

(2) Through burdensome city taxes on the transit companies.
  a. Gross taxes.
  b. Net taxes.
  c. Occupation taxes.
  d. Franchise taxes.
  e. Seat taxes.
  f. Vehicle taxes.
  g. And many other taxes and assessments (bridge rental fees, for example).

(3) Through housekeeping charges which single out the transit companies--charges for
  a. Snow removal.
  b. Spreading and then cleaning up cinders.
  c. Tearing up abandoned trackage and resurfacing the streets.
  d. Repairing damage to city streets (not assessed against trucking firms, for example).

(4) Through raids upon the transit companies or authorities funds by various public agencies (of which even the municipal transit lines are the victims). (a) By streets and park departments for street damage; (b) by civil service commissions for hiring and firing drivers.

The elimination of the streetcar, in many ways a remarkably efficient public carrier is generally blamed upon the demands of the automobile driver. "One-way street programs, elimination of curb parking, restrictions on turning movements are all directed toward making streets more efficient. Almost all have been directed toward providing means for driving our autos where and when we choose." (212, p. 120)

Fortune Magazine, in a survey made in 1957, found that the motorist enjoys a marked advantage in speed over the mass transit passenger. During a peak period on the most heavily used routes the motorist averages (in the 25 largest cities of the United States) 20 miles per hour, while the mass transit passenger--streetcar, subway, or bus--averages 13 miles per hour. Only in New York, San Francisco, and Newark did mass transit do better than the national average for automobiles, and only in those three cities did mass transit move faster than automobile traffic. Here is a very tangible reason for the preference for the automobile.

## The Problem of Urban Street Room

L. F. Howard cuts to the heart of the urban street congestion problem in the following mathematical summary: "The population of metropolitan areas is increasing four times faster than the national average. The day-to-day movement of people and goods is increasing about three times as fast as the population growth. Some two-thirds of this movement of persons and goods takes place on city streets which make up roughly one-tenth of the nation's highways." (212, p. 123)

With this enormous increase in the burden placed upon urban streets, the United States in 1957 had fewer than 1,500 miles of high

capacity urban expressway. Under the Federal Aid Highway Act, by 1970 it will have 5,500 more miles in 90% of all cities of more than 50,000. Provision for more city street mileage, either with or without federal aid, is falling far behind the soaring demand for more room to drive in the cities.

In 1945, automobile registrations in the United States numbered 31,035,420, including buses and trucks as well as smaller vehicles. Assuming an average bumper to bumper length for each vehicle of 20.3 feet, this would represent 119,321 miles of vehicles. There were, in 1945, 313,000 miles of city streets.

In 1956 automobile registrations in the United States numbered 65,153,810. Assuming the same average length per automobile (a very conservative assumption), this would represent 250,496 miles--a gain of well over 100% in 11 years. But there were, in 1956, only 373,000 miles of city streets, an increase over 1945 of only 60,000 miles--a gain of less than 20% over the 11-year period. Very little of this new mileage was expressway facility.

In 1959, estimated automobile registrations will be 70,416,000. Bumper to bumper, the vehicles represented here will stretch for 270,728 miles, with the effect that city street mileage will be still farther behind in the job of making room.

A rapidly rising obstacle to providing more city street mileage for the automobile is the mounting cost of urban arterials. Boston has embarked on a plan which calls for an inner belt route around the central business district (85% of motorists entering Boston go to the central business district), an outer belt route (Massachusetts State Route No. 128) at a radius of 15 miles from the central business district, and a number of

expressways fanning out like spokes from the central business district. The first one and one-half mile section of the central artery (which will be 30% of the inner belt route) cost $55 million, including $15 million for the right-of-way. (172, p. 131)

Another depressing condition found in providing more street mileage in cities is the almost instantaneous realization of full capacities when new arterials are opened. In Chicago the Congress Street Expressway was designed for an estimated maximum vehicular load of 96,000 vehicles per 24 hours. This maximum was expected to be reached in 1960. In 1959 the expressway was not yet completed and already it was carrying 115,000 vehicles per 24-hour period. The Los Angeles Hollywood Freeway, designed for an estimated maximum vehicular load of 100,000 vehicles per 24-hour day, was carrying, one year after it was opened, 170,000 per day. The same pattern appears in all metropolitan centers when new arterials are built (380, pp. 19-20).

While the freeway and the expressway furnish a dramatically fetching picture of a solution to the crying need for more city street mileage, grave doubts are being expressed in some quarters that they are, in fact, the solution that they seem to be.

"The freeway idea for a city has been oversold," declares G George H. Herrold, formerly Planning and Zoning Consultant for St. Paul, Minnesota. "The freeway is a fine idea for travel between cities, but for intra-city travel it is a great misconception of the needs of an urban community." (226)

Mr. Herrold lists several objections to the freeway solution:

(1) The uprooting of people, socially and economically.

(2) Loss of taxpaying property.

(3) Disturbance of public utilities.

(4) Loss of time and mileage in getting to and from a freeway.

(5) Moving of businesses and obsolescence of business properties, creating new "blighted areas".

(6) Problems within the freeway itself--policing, giving fire protection, servicing for accidents and emergencies.

(7) The erection of a social and economic moat or Chinese Wall which divides the city.

It would appear that many of the costs of a freeway are the hidden costs, which, to be realistic, must be added to the more obvious ones. The validity of Mr. Herrold's fourth objection may be indicated by the case of the Edens Expressway in Chicago.

The North Shore traffic corridor entering the city of Chicago is about five miles wide. It contains Edens Expressway, two railroads, and four highways which are not expressways. Edens Expressway is 13.5 miles long. About 70% of the traffic in the corridor which is going the full 13.5 miles uses Edens. For shorter trips the use drops to about 20%. The decline is assigned to the fact that it takes too long to get on and off the expressway to make its use practical for the shorter trips (390).

In addition to the problem of providing more street room in our cities for moving vehicles, the national preference for the automobile poses another problem in the matter of providing parking space in the downtown areas for the vehicles after they arrive. The magnitude of this problem may be suggested by pointing out that if everybody who enters upon Manhattan Island on an average weekday drove his own automobile, the whole island below Fiftieth Street would have to be given over to parking garages (41, p. 6).

## The Automobile Versus Mass Transit

With congestion rapidly increasing upon city streets and the means of relieving it increasingly difficult to come by, the question naturally arises, why not turn back to mass transit--back in the sense that the most prosperous times for the mass transit industry seem to be in the past. The Victor Gruen plan for Fort Worth envisions such a movement. Gruen assumes that to make the plan work a city which now has 17% of its travelers using mass transit will become a city in which 45% of its travelers will use it. The public at present seems to be showing a certain reluctance to accept this solution.

In 1957 the total United States investment in mass transit was under $4 billion. By 1969, the United States, by contrast, will spend $100 billion on roads. By 1969, under the Federal Aid Highway Act, $12 billion out of federal taxes alone will be spent on high capacity urban expressways.

The historical trend may be seen in this break-down of expenditures. In constant (1956) dollars, Americans spent $1.8 billion in 1929 on mass transit. In that same year, they spent $10 billion on automobile transportation. Automobile transportation here includes cars, fuel, repairs, parking fees, and tolls, but not depreciation. In 1957, they spent $1.5 billion on mass transit, $27 billion on automobiles. About half of the expenditure for automobile transportation is for travel within cities.

During the past three years, rail rapid transit riding has shown a tendency to level off in volume, but the volume of surface transit riding has continued to drop (212, p. 123).

What are the reasons behind people's choice of one mode over the other? They are hard to ascertain, and little has been done in this

area. During the summer of 1956, the Cook County Highway Department (Illinois) undertook a transportation usage study. Interviews were obtained from 2,110 persons in Cook County, 806 mass transit riders, 1304 automobile riders. The study gave the results in Table I-8 (380, p. 55).

It is clear by this table that mass transit loses heavily in the time element where trips to outlying districts are involved, a loss which present-day mass transit with its relatively stiff routing and scheduling finds difficult to remedy. It is also clear that mass transit loses very heavily where comfort is involved, a matter which mass transit can more easily change.

There seems to be much opinion to the effect that the cost of owning and driving an automobile has little effect upon automobile users. The Illinois State Mass Transportation Commission gives it as its opinion "that the cost of driving an automobile is widely ignored or underestimated by most of the residents in this area." Donald Hyde, General Manager of the Cleveland Transit System, pointed out in 1955 that transit workers with free passes on the transit system drove their own automobiles in preference to taking advantage of the free ride. Francis Bello says that "the automobile is not enough costlier so that people will readily forego the greater convenience and comfort it offers." It might be further observed that since there is undoubtedly a psychological satisfaction or fulfillment connected with driving one's own car, it is a very difficult element to account for in any costing procedure.

The Cook County Highway Department further found that if mass transit riding costs one-tenth of the cost of automobile riding, 60% of travelers will ride mass transit. If transit costs are one-half of automobile costs, 15% will ride transit. If costs are equal, 5% will ride transit (380, pp. 53-54). This seems to bear out the statement of Bello

TABLE I-8

Reasons for Choice of Mode of Travel

(Given in Cook County Transportation Usage Study)

| Reasons | For Trips To or From: | | | | Percent of Total Mass Transit | Percent of Total Auto | Percent of Grand Total |
|---|---|---|---|---|---|---|---|
| | Central Business District | | Outlying Areas | | | | |
| | By Mass Transit | By Auto | By Mass Transit | By Auto | % | % | % |
| Less Time | 127 | 38 | 92 | 428 | 27.2 | 35.7 | 32.4 |
| Comfort | 34 | 37 | 15 | 281 | 6.1 | 24.4 | 17.4 |
| Car Necessary | 0 | 41 | 0 | 222 | 0 | 20.2 | 12.5 |
| No Other Means | 2 | 8 | 120 | 140 | 15.1 | 11.3 | 12.8 |
| Less Walking | 34 | 5 | 95 | 35 | 16.0 | 3.1 | 8.0 |
| Less Cost | 58 | 0 | 44 | 9 | 12.7 | 0.7 | 5.3 |
| All Other | 59 | 4 | 126 | 56 | 22.9 | 4.6 | 11.6 |
| | 314 | 133 | 492 | 1,171 | 100 | 100 | 100 |

above. It should be added that Bello believes that average mass transit fares and average automobile costs to the user per mile are very close together. As he sees it, the average transit fare is about 4 cents per mile, while the automobile costs about 5 cents per mile to own and drive (including depreciation). Putting these figures together with the results of the Cook County attitude survey shows us why mass transit is in trouble. It may be noted, however, that these figures apply to mass transit as the public now thinks of it. Should its characteristics be markedly changed, there is no reason to believe the figures cited would remain applicable.

Since time for travel seems to be a major factor in choice of mode, it is apropos to compare mass transit with the automobile in this matter. With present equipment and with half-mile runs between stops, the attainable schedule speed for rapid rail transit is about 25 miles per hour. To compete with the automobile this speed would need to be upped to 45 to 50 miles per hour. To attain such a speed, rail rapid runs would have to be two miles in length between stops; and patrons, always quick to complain about cuts in service, would be seriously inconvenienced.[1]

The 1957 survey conducted by Fortune Magazine earlier referred to indicates that starting from a city center on the most heavily congested route during a peak traffic period, the motorist in most large American cities enjoys a substantial advantage in speed (and, therefore, in time saved) over the mass transit rider.

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[1] In the present state-of-the-art, rapid transit schedule speed attainable with two-mile runs between stops would be 48 miles per hour, according to L. F. Howard. Average speed for rail rapid in Chicago, according to the Chicago Transit Authority, is 22 miles per hour.

According to the Cook County Transportation Usage Study (380), if rapid transit running time were one-half automobile running time, 95% of trips would be made by rapid transit. When rapid transit time equals automobile time, 40% of trips are made by rapid transit. If rapid transit time were twice that of the automobile, about 10% of trips would be made by rapid transit.

To move out of the somewhat hazy realm of rider preferences into the more clearly defined area represented by the mathematics of capacities, we find the argument for rapid transit heavily fortified. A single lane of expressway is capable of carrying 2000 persons per hour in automobiles. The total capacity of an 8-lane expressway (4 lanes each way) is 8000 persons per hour. To cite an actual example, Chicago's Lake Shore Drive, an 8-lane expressway, has two reversible lanes on either side of the median. With six lanes of traffic moving one way, Lake Shore Drive carries 30,000 rush-hour passengers per day. By contrast, a double-track rapid transit line (one track each way) carries 63,000 rush-hour passengers per day. A two-track rapid transit system with a capacity of 40,000 passengers per hour would be the equivalent, in load capacity, to five 8-lane expressways. Figures like these lead Frederic Gardiner, Chairman of the Council of Metropolitan Toronto, to say that one dollar spent on rapid transit is worth five dollars spent on more highways and parking facilities.

Interestingly enough, the proponents of rapid transit and the proponents of more freeways argue against each other on the same basis--saving money out of transportation funds for other needed municipal outlays.

Thus we have the opinion of Mr. Stanley Berge, Professor of Transportation at Northwestern University:

> "Why build metropolitan freeways beyond base load requirements just to take care of 20 rush hours a week? Why not build a transportation plant 20 times as efficient as freeways to take care of rush hour peak demands? This would save vast areas of valuable land for industrial, commercial, and recreational development. Why take 20 times as much land off the tax rolls for highways? Intelligent provision for efficient rush-hour travel facilities will make automobile transportation more pleasant, efficient and economical." (43, p. 134)

And again Mr. Berge states:

> "Since the rush-hour carrying capacity of electric railways is 20 times that of automobiles on limited access freeways, it is clear that every dollar spent on metropolitan electric railway rights-of-way releases 19 highway dollars for highway improvements outside metropolitan rush hour routes. Why build metropolitan freeways beyond base load requirements just to take care of 20 rush hours a week?" (320)

Yet we have Francis Bello referring to Mr. Wilfred Owen of The Brookings Institution as believing that it is wrong to subsidize mass transit on a large scale when the community dollar is needed for so many other things. "The great virtue of the new highways and expressways is that they can be paid for by the users." [1]

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[1] It is worth noting again that there are hidden or tangential costs in connection with freeways which are not always considered. For instance, it costs five times as much to police, provide fire protection for, and give welfare to the blighted areas created by new freeways as those areas can return in taxes, says Mr. George H. Herrold. Mr. Herrold does not seem to take into account the off-setting effect of increased tax revenue gained from areas improved by the new freeways.

## The Changing Picture of Mass Transit

The term "sick industry" is often applied to the mass transit business in our major cities. How applicable it is may be indicated by Table I-9 showing the decline, in percentages, in mass transit riders in selected cities of the United States between 1950 and 1955.

Table I-9 could be expanded to include 47 major American cities, and there would be little alteration. The picture in all of these cities appears to follow this course:

Declining Load Factor ⇄ Higher Fares and Curtailed Services

This decline seems to be characteristic of both municipally owned and privately owned companies. Four cities are generally regarded as having efficient rapid transit systems--Cleveland, Chicago, Philadelphia, and Cincinnati. The first two have municipally owned systems. Philadelphia's is publicly owned, privately operated. Cincinnati's is privately owned.

Naturally, such an industry is not in a position to attract investment capital or to expand its facilities where it is not subsidized. When Miami, Florida, was dissatisfied with its private transit company and tried to peddle the franchise, it asked for bids from 53 transit companies. Fifty did not bother to answer the invitation. The three which did sent a brief "no bid". Congress met a similar lack of enthusiasm when it attempted to supplant the old Capital Transit Company in Washington about the same time (447).

## TABLE I-9

**Decline in Mass Transit Riders in Selected Cities of the United States Between 1950 and 1955 (in percentages)**

| City | Percent |
|---|---|
| Tulsa | 55 |
| Los Angeles | 52 |
| Oklahoma City | 50 |
| Pittsburgh | 50 |
| Fort Worth | 39 |
| Dallas | 35.7 |
| Minneapolis | 35 |
| Seattle | 34.7 |
| Cincinnati | 33 |
| Toledo | 32.9 |
| Milwaukee | 32 |
| Baltimore | 32 |
| Washington | 29.4 |
| Philadelphia | 25 |
| Cleveland | 20.8 |
| Detroit | 20 |
| St. Paul | 14.5 |
| Chicago | 13 |
| Kansas City (Missouri) | 10 |
| Boston | 6 |
| Atlanta | 3 |

The principal cause of the disease which is undermining the transit industry seems to be the private automobile. "We've found no successful approach which could attract customers out of their cars", says Mr. W. H. Spears of National City Lines, Inc., which owns outright the systems of 43 cities and has a controlling interest in the systems of four others.

Other sources of the attrition "wasting away" the mass transit industry are:

(1) The dispersal of suburban populations thinly over wide areas, which eliminates the mass origins upon which the industry feeds. This matter has been discussed earlier. This development is, of course, linked with the public preference for the automobile.

(2) The five-day week, which has ruined Saturday business for mass transit.

(3) The popularity of home attractions such as television, which has cut into evening trade.

(4) An unfavorable public image which grows as fares are increased, service is cut, and equipment deteriorates.

(5) Action by politicians who, rightly or wrongly, cause trouble for the transit companies by financial levies and the encouragement of competing modes of travel.

(6) Peaks in riding. The fact that equipment and manpower sufficient to handle the traffic demands for a few rush hours per week must be obtained and then maintained through the much longer slack periods is a basic weakness in any mass transit industry. By way of illustration, commuter cars in the New York area are in use, on an average, just 20 hours per week.

Faced with mounting losses, transit companies and authorities show several classic responses.

Rise in Fares. This method of stanching the "bleeding away" of transit revenue has very limited effectiveness. In 1955, 40 American cities experiencing raises in transit fares reported no halt in the decline in transit revenue, and 7 cities found that increased fares had stopped the decline. Fare levels seem to have little to do with decline in revenue. Throughout the period 1950-1955, New Orleans, with a 7¢ fare, declined steadily, as did Providence, Rhode Island, with a zone fare system reaching a 41¢ maximum. Donald C. Hyde, General Manager, Cleveland Transit System, doubts that there would be many more riders if the service were free. He points out that many transit workers, with free carrying passes, drive their own cars to work.

Cut-backs in Service. In 47 cities surveyed in 1955, 18 had cut back feeder service within the year. Seven had no feeder service. This hurts the increasing number of householders who live off the main lines and night travelers generally, as was illustrated when Omaha stopped all feeder service at 7 p. m. Since feeder lines are the earliest casualties of a retrenchment program and the program usually includes increases in fares, the public image of mass transit suffers; as the public complains, "They're charging us more and giving us less". [1]

Promotional Measures. A partial list of ideas generated to boost the use of mass transit facilities is given below, together with the names of cities where they have been tried. Almost all are demonstrated failures.

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[1] It should be pointed out here that reversing the two processes listed above does not seem to help transit revenues. National City lines added service in Long Beach, Stockton, and St. Louis and cut fares in Long Beach. Of the experiment, W. H. Spears reports, "We lost our shirts".

a. Free baby strollers for downtown shoppers (Nashville);

b. shelters at outlying transfer points (Nashville);

c. free rides in downtown area (Toledo);

d. reserved seat, "membership" buses (Cincinnati);

e. low fare shoppers' specials (Fort Worth, Pittsburgh Detroit);

f. low off-peak fares (Dallas lost $1500 per day on this);

g. crosstown service to shopping district (Fort Wayne lost $3000 in 3 months);

h. free parking (Louisville, Omaha, Detroit);

i. round trip for one-way fare courtesy downtown stores (Omaha)--"Not even moderately successful", says the transit company president, L. G. Barnes;

j. expresses to ball games, race tracks, parks (Omaha found that the advertising cost more than the profit);

k. music in buses (Omaha found the patrons rebelled);

l. special low fares for the elderly (Detroit).

The case of Detroit might illustrate the failure of symptom treatment to increase transit revenues. In 1955, Detroit offered:

(1) A 10¢ fare for senior citizens;

(2) A loop service for 10¢;

(3) Reduced fares for shoppers;

(4) A "park free and ride the transit" service;

(5) Deluxe rides to special areas.

The public reacted with almost unanimous apathy. The total income of mass transit dropped more than $3 million. Profits were cut in half. The new measures were dropped.

Functional and Organic Engineering Improvements. There has been some serious attempt in a few cities to give the public faster, more comfortable, more convenient service, and to improve the public image of mass transit. In Chicago, Cleveland, and Philadelphia, for example, higher speeds have been achieved by instituting a skip-stop system, which seems to be more effective in Chicago than an express system. In Philadelphia, skip-stop has saved, on the subway, an average of five minutes per ride. Chicago has spent and is spending large sums on new all-metal subway cars and odorless propane buses. During the year 1959, the Chicago Transit Authority added 130 of these propane (LP) buses to its fleet (85, pp. 3-4). The Authority has brought a 70 mile per hour all-steel train through the experimental stage. Philadelphia in the mid-fifties spent $25 million on new vehicles. Yet Cleveland, Philadelphia, and Chicago have made little dent in the downward trend of patronage. In the first few months of 1960, Chicago's transit patronage had decreased rather considerably. Some improvements, like exclusive bus lanes in downtown areas (Nashville, Chicago), have perhaps made more enemies among motorists than friends among transit riders.

Public Aid. This takes two forms: (1) direct subsidy, and (2) relief from taxes and levies. Harry L. Severson, economist and authority on municipal bonds, foresees an imminent upturn in city borrowing for modern transit systems. Starting in 1961 or 1962 at about $500 million a year, he thinks it will climb by the late 1960's to about $3 billion a year--a little more than half the rate of current highway construction. In 1955, 24 cities eased up on their financial demands on metropolitan

transit systems, seven states gave tax relief to all transit firms. Des Moines waived her gross receipts tax, Milwaukee her franchise tax, Pittsburgh her bridge rentals. Dallas, which took $319,367 in 1953, took only $30,000 in 1956. Some of this new look in public via politician attitude is owing to a recognition on the part of businessmen of the need for mass transit facilities. In Atlanta, when the transit firm "folded", seven department store owners took over the business, lost $5,000 the first year, and made $20,000 the next year.

Building Charter Bus Business. San Antonio Transit Company increased its charter business 33% with its party cruisers, with cut-off tops and movable lawn chairs on an open deck. Toronto, Canada operates 14 buses on "mystery rides" into the country on Sundays, thus using equipment which would otherwise be idle during an off-peak period.

## Chapter 3. A Broad-Brush Summary

This part of the report has been presented to better define the problem of airport transportation and the context in which it exists. It has been a brief sketch of some of the most critical elements. The section on metropolitan transportation was necessary in order to illuminate the basic considerations which any mode of transport must face. Also, it is within these considerations that part of our search for evaluative parameters must take place.

In broadest-brush terms, the situation with respect to airport transportation might be outlined as follows.

(1) Airline passengers constitute almost 1/2 of the daily airport user population.

(2) At present, an overwhelming majority of airport users travel to and from the airport in automobiles.

(3) In the not-distant future, it is likely that the automobile, as we now know it, will not be an acceptable mode of transport to and from the airport.

(4) The local origin-destination pattern of airport users tends to be highly dispersed with few concentrations of high density.

(5) Various modes of mass transit, as we now know them, are not likely to provide a satisfactory solution.

(6) Comprehensive means are needed to evaluate new concepts proposed to resolve the problem.

(7) Airport transportation problems can not be resolved independently from the general urban transportation problem, but airport transportation is of more direct relevance and concern to the airline industry, or, more broadly, the air travel mode, than it is to the municipality in which it occurs.

# PART II. CASE STUDIES OF AIRPORT TRANSPORTATION IN FOUR CITIES

The scope of the present study is general, covering airport transportation and not specific to any one locale. At the outset of the study, it was reasoned, however, that it would be of particular value to study a number of specific cities in considerable detail to provide a foundation for a general understanding of the problem, to obtain specific data where it was available, and to aid in the search for basic parameters which could be used in the comparative evaluation of various systems. To this end, four cities were selected for special study.

A vast amount of material relevant to transportation problems is available on some cities, notably New York and Chicago. It is not the purpose of this report to duplicate the efforts of the many studies listed in the bibliography. Rather, in this Part, our purpose is to highlight the facts and figures for each city which are highly pertinent to the airport transportation problem.

In trying to establish criteria by which the cities could be chosen, we found that a sound argument could be given in favor of almost any large hub airport in the country and for that reason the actual choices can be considered arbitrary. We wanted to look at situations as different as possible and about which there was as much information as possible. From the 13 cities[1] that were actively considered, four--New York City, Chicago, Washington, D. C., and San Francisco--were selected. A number of others could have been chosen equally as well.

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[1] New York City, Boston, Philadelphia, Washington, D. C., Atlanta, Cleveland, St. Louis, Chicago, Detroit, Houston, Seattle-Tacoma, Los Angeles, and San Francisco.

A chapter is devoted to the airport transportation situation in each of the four cities. In each, information is presented concerning population and geography, the airport, airport transportation service, local origins and destinations of passengers, modes of airport travel, and planned future developments.

In Washington, D. C., as part of this study, a survey was conducted at Washington National Airport to establish local origins and destinations of passengers, their modes of travel, and a number of other points of relevant information. The pertinent results of the survey are presented in the chapter on Washington, D. C. The survey itself and a more detailed analysis of results are presented in a separately bound Appendix B to this report, entitled "A Survey of Local Origins and Destinations of Users of Washington National Airport".

## Chapter 1. Airport Transportation in the Chicago Metropolitan Area

### The Chicago Metropolitan Area

The Chicago Metropolitan Area may be named and defined in any one of several recognized and accepted ways.[1] Since Chicago Midway Airport and O'Hare International Airport are the two airports of national and international significance which serve it, the largest of these areas--the Chicago-Northwestern Indiana Standard Consolidated Area of eight counties--is appropriately considered the Chicago Metropolitan Area in this study. However, some of the available data will require a report on a somewhat smaller area centering upon the city of Chicago itself.

The land area of the Chicago-Northwestern Indiana Standard Consolidated Area is 4,653 square miles, somewhat more than twice the land area of the state of Delaware. Of this, the Chicago Standard Metropolitan Statistical Area takes up 3,714 square miles (440, 302).

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[1] The 1950 census designated the Chicago Standard Metropolitan Area as a six-county unit comprising Cook, DuPage, Kane, Lake, and Will counties in northeastern Illinois, and Lake county in Indiana. This designation is still used in some statistical reports. The 1960 census defines the Chicago Standard Metropolitan Statistical Area as consisting of six counties in northeastern Illinois--Cook, DuPage, Kane, Lake, McHenry, and Will. United States governmental agencies will now use this this designation in their reporting of data. In addition there is the Chicago-Northwestern Indiana Standard Consolidated Area, so named by the Bureau of the Budget, and consisting of the northeastern Illinois counties of Cook, DuPage, Kane, Lake, McHenry, and Will, and the Indiana counties of Lake and Porter. This is simply a combination of the Chicago Standard Metropolitan Statistical Area with the newly defined Gary-Hammond-East Chicago Standard Metropolitan Statistical Area (446).

The estimated population of the Chicago-Northwestern Indiana Standard Consolidated Area in 1960 is 7,049,000. The estimate for 1970 is 8,745,000, and for 1980 it is 10,623,000. (445)

The growth rate of the Chicago-Northwestern Indiana Standard Consolidated Area is 2.4% per year. Breaking this down between the two states involved, the growth rate of the six Illinois counties is 2.3% per year (about 25% for the decade 1950-1960), while the growth rate for the two Indiana counties is a faster 3.5% per year (39% for the decade 1950-1960). It is expected that over the period 1960-1980 the growth rate of the Indiana counties will be stepped up to 4.1% owing to expanding employment in the steel industry.

"Northeastern Illinois (the Chicago Standard Metropolitan Statistical Area) is growing faster than the state of Illinois or the nation as a whole... Northeastern Illinois is growing at about the same rate as that displayed by the nation's 168 Standard Metropolitan Areas taken as a whole. The New York area seems to be growing slower than Northeastern Illinois while the Los Angeles area is growing much faster." (446)

## Airports Serving Chicago

The Chicago-Northwestern Indiana Standard Consolidated Area is served by two major airports handling scheduled flights:

> Chicago-Midway, located at 5700 South Cicero Avenue. This has been long regarded as Chicago's municipal airport, and, with its more than 1,200 plane movements per day, is the busiest airport in the world. It is, at present, operating at 100% of capacity, and because of limitations imposed by its location it has now exhausted its potentiality for expansion.

Chicago O'Hare International, located at Bryn Mawr Avenue and Wolf Road. This is the only commercial airport in the Chicago area whose landing strips can accommodate turbojet planes, and which has a high potentiality for expansion--and so the pressure of business on it is increasing rapidly.

In addition to these two major airports handling scheduled flights, the Chicago-Northwestern Indiana Standard Consolidated Area is served by:

Merrill C. Meigs Field, located on a 70-acre island off the lake front at 15th street. Meigs Field is for the use of corporate and private aircraft, and the only scheduled commercial flights into and out of it are by helicopter. It is heavily used and is, in fact, the busiest single-strip airfield in the United States.

Together these three airports form what is locally referred to as "the Golden Triangle", whose sides measure 42 air route miles, collectively. In terms of direct air distances it is 8 1/2 miles from Midway to the central business district (CBD), 13 1/2 miles from O'Hare to the CBD, 12 1/2 miles from O'Hare to Midway. In terms of conventional ground travel distances, it is 17 miles from O'Hare to the CBD, 12 miles from Midway to the CBD, and slightly less than two miles from Meigs to the CBD. (In automobile driving time Meigs Field is 5 minutes from "Airline Row", the corner of Wabash and Monroe Streets.)

While helicopters move around the Golden Triangle, stopping at each airport, fixed-wing aircraft on commerical schedules are not permitted to serve both Midway and O'Hare on the same flight.

Nineteen scheduled airlines serve the Chicago-Northwestern Indiana Standard Consolidated Area through Chicago-Midway and Chicago O'Hare International Airports. Beginning with the fall of 1959 there has been a rapidly accelerating shift of operations from Midway to O'Hare. As of the summer of 1960, nine domestic trunklines, one local service carrier, and six international airlines served O'Hare. (165)

During the first eight months of 1958, Midway and O'Hare together had 261,972 scheduled commercial plane movements. During the same period in 1959, the number had risen to 263,697 scheduled commercial plane movements for the two airports (137). By the close of 1959, Midway was close to the 350,000 mark in plane movements. The rapid increase in traffic density at O'Hare is evident in the fact that in April, 1959, the first full month of turbojet operations at O'Hare, there were 94 arrivals and departures per day, and by April, 1960, there were 272 (165).

In 1949 Meigs Field had 23,589 landings and takeoffs. In 1959, the number had increased 314% to 97,656. The present configuration of Meigs Field limits its capacity to about 120,000 movements annually (77).

Beginning with the year 1955, the first year of scheduled commercial flight operations at O'Hare Field, the mean daily passenger arrivals and departures are given in Table II-1 below.

TABLE II-1

Mean Daily Passenger Arrivals and Departures
at Midway and O'Hare

| YEAR | MIDWAY | O'HARE |
|---|---|---|
| 1955 | 25,027 | 178 |
| 1956 | 24,286 | 1,931 |
| 1957 | 25,859 | 2,786 |
| 1958 | 25,578 | 3,453 |
| 1959 | 27,571 | 5,880 |

The growth of O'Hare and the concomitant relieving of the pressure on Midway may be seen in the figures for passenger volumes at the two airports during January, February, March, and April of 1959 and the same four months of 1960. During the 1959 period O'Hare's passenger volume was 378,049, Midway's 3,148,880. For the 1960 period, O'Hare's was 1,361,100, Midway's 2,383,019. This was a loss for Midway of 766,000. It is predicted that O'Hare will almost double its passenger volume in 1960 over the volume for 1959. And it is further predicted that by 1965, O'Hare will be handling three-fourths of the total passenger volume for the two airports. The Department of Aviation of the city of Chicago expects 2,100,000 passenger departures from O'Hare Field in 1960--a 95% increase over 1959. In 1961, the Department expects 2,940,000 departures, and, in 1965, 6,820,000 (165).

The Chicago Area Transportation Study found that just over 10.5 million person trips were made on the average weekday in 1956 (76). Only 25,000 of these trips were concerned with air transportation, and not all of these were to airports.

About 13% of the terminal population at Midway Airport consists of employees in various capacities (185). O'Hare Field has a population of considerably more than 3,000 workers at present.[1]

## Airport Transportation in Chicago

There are eight modes of travel in-being in the Chicago-Northwestern Indiana Standard Consolidated Area which are used, or which

[1] Personal interview with Mr. Louis M. Traiser, Staff Engineer, Chicago Transit Authority, August 4, 1960.

might in theory be used, to convey members of an airport population between the airport and their point of origin or destination in the area: the private automobile, the taxicab, the limousine (airport bus), the helicopter, the city bus, the subway, the elevated railroad, and the suburban railroad. The first four are now in use. Figure II-1 shows the relative use of these four modes on a summer day in 1955.

The Suburban Railroad. There are, at present, no active plans for serving Midway or O'Hare with a suburban railroad line. The Northwestern Railroad proposed an electric shuttle train service between O'Hare and the central business district, to utilize the median strip of the Northwest Expressway insofar as possible. But Cook County engineers declared the plan to be not feasible, and it is now dormant. Since there was little investigation of the proposal at the time it was made or since, it may be revived.[1]

The City Bus, the Subway, and the Elevated Railroad--The Chicago Transit Authority. The Chicago Transit Authority operates the city buses, the subway lines, and the elevated rail lines within the city of Chicago. In 1959, it took delivery on 96 all-metal, light-weight, high-performance rapid transit cars and 130 propane-fueled (LP-gas) motor buses. (85, 88)

But it is less than enthusiastic about the possibility of serving O'Hare and Midway. As one Chicago Transit Authority official put it to the present writer, "If our buses got 1% of the passenger business at O'Hare, it would amount to about two bus-loads per 24-hour period."[2]

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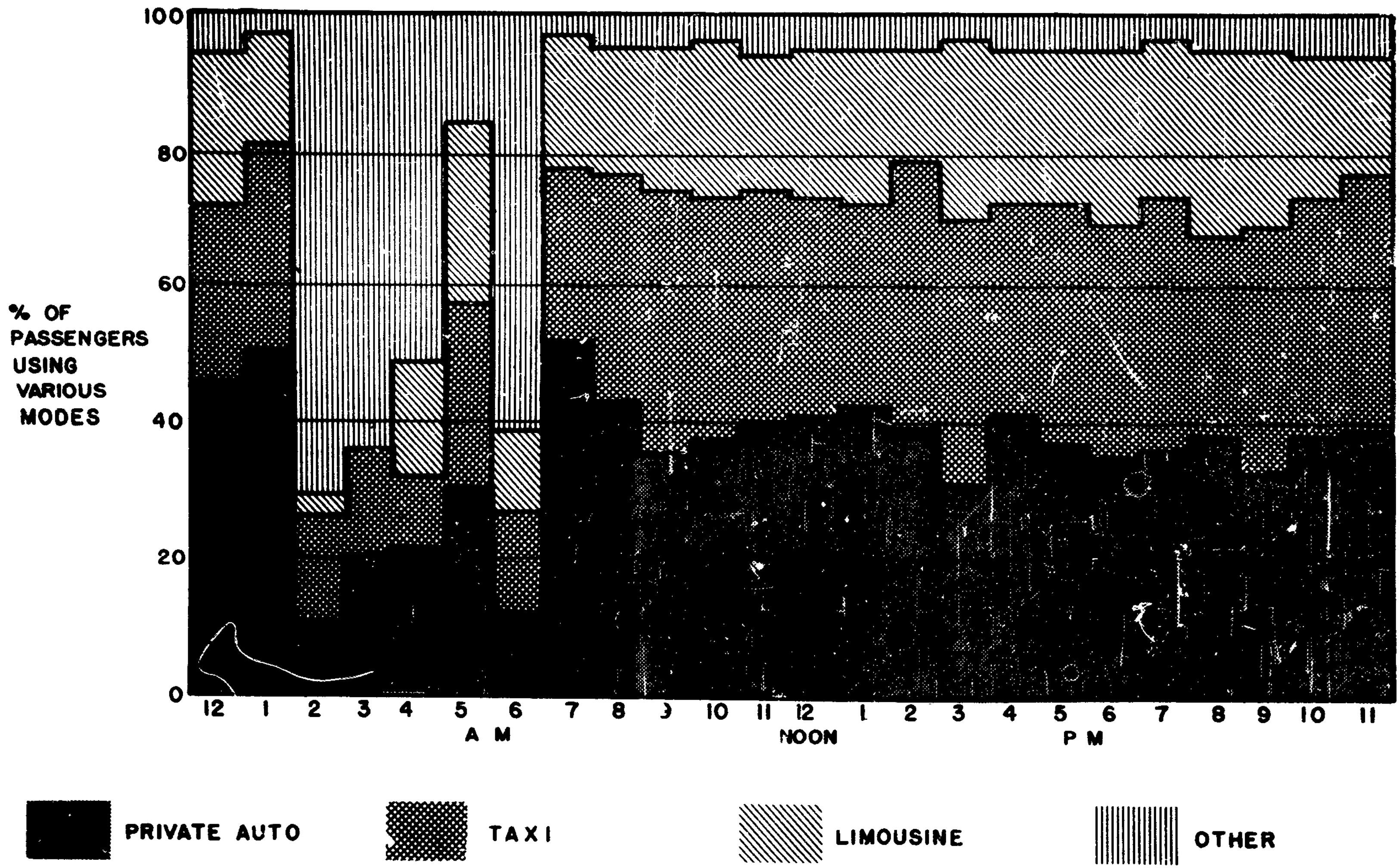
[1] Personal interview with Mr. Randall Cooper, Director Chicago Central Area Committee, June 30, 1960; personal interview with Mr. Edwin T. Haefele, Lecturer and Assistant Director Transportation Center, Northwestern University, June 27, 1960.

[2] Interview with Traiser, cited on page 62.

FIGURE II-1

MODE OF GROUND TRANSPORTATION TO AND FROM MIDWAY

MID-SUMMER DAY, 1955 BY TIME OF DAY




SOURCE: (4)

At present there is no Chicago Transit Authority (CTA) service to the vicinity of O'Hare. CTA buses serve Cicero Avenue, which runs past Midway, but they are not allowed within the gates of the airport. On an average weekday in 1955, almost precisely 1% of arriving and departing passengers used CTA buses to the gates of Midway (184).

The CTA has been approached by airlines which want CTA service for airport employees. Late in the summer of 1960, the Authority had completed a survey of employee origins and times of arrival at and departure from the airport which showed that such a service is not feasible. The survey concerned itself, as did the airlines' request, with O'Hare Field. It was discovered that the more than 3,000 employees of the Field are very evenly scattered over almost the entire metropolitan area of Chicago. The highest concentration of workers in any one sector was 29. One of the highest concentrations--20--was in a sector on the far south side of the metropolitan area, diagonally across the area from O'Hare. It was further discovered that 41% of O'Hare's workers check in at the airport before 7 a. m. (with the highest peak of the day at 6 a. m.), and 41% check out of the airport at or after 11 p. m. These would be times of day when it would be most uncomfortable and even dangerous for employees--especially female employees--to wait at a loading platform or stop or to debark at a platform or stop. These would also be times when the headways between elevated trains or buses that employees would have to transfer to would be longest with the longest concomitant waits possible. The conclusion of the CTA[1] is that

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[1] Interview with Traiser, cited on page 62.

the employee transportation problem at O'Hare Field can best be solved by motor pools among the employees or by individual driving.[1]

The following are specific objections put forth by CTA officials to serving O'Hare and Midway:

1. Air travelers are not the mass transit type. Most of them are traveling on expense accounts and are primarily interested in speed and convenience, rather than cost.[2]

2. CTA funds are limited, and what is available for plowing back into the business had best be used for improvement of existing facilities and expansion within the city limits or at least where mass origins create a more pressing demand for new or improved service.[3]

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[1] It should be remarked in this connection that the geographic distribution of O'Hare employees described above is the result of a mass movement of Midway workers to O'Hare that has occurred during the past year, since the fall of 1959. Many of these workers have not changed the geographic location of their homes to correspond with the geographic location of their new job assignments. This accounts for many who now live on the south side and work at O'Hare on the far northwest side, and is a situation which will tend to correct itself in time.

[2] Personal interview with Mr. H. L. Polland, Director of Public Information, Chicago Transit Authority, August 4, 1960.

[3] Interview with Polland, cited above.

3. The airports do not provide a sufficient volume of business and what business there is peaks at times of the day which do not correspond with peak periods in other parts of the CTA system.[1]

4. Speeds attainable by mass transit vehicles are too low to satisfy air travelers. The present average speed for rail rapid is 22 m.p.h. The present average for buses outside the CBD is 11 m.p.h. Inside the CBD it has dropped to 3-4 m.p.h. And for buses conditions are worsening to the point of strangulation of movement. If funds were available, CTA could very shortly put into operation rail rapid trains capable of running at up to 70 m.p.h., but with the present lack of money for capital outlay there are no detailed plans for doing so.[2]

5. Baggage handling presents an insuperable problem. It would be possible, though awkward, to allot every other seat on a mass transit vehicle to baggage, but the present employees on CTA vehicles are not conditioned to give the air traveler the kind of assistance and service that air travelers expect, although they could help in the a ıal loading of passenger baggage.[3]

<u>The Private Automobile</u>. According to available statistics the private automobile is the most popular mode of ground transportation used by air travelers in going to an airport in the Chicago area (see Table II-1). It falls just short of the taxicab in popularity with terminating passengers. This conclusion, based on statistics obtained in reference to Midway only, is true if all passengers are considered as a whole; it is not true of subgroups originating or terminating in certain metropolitan zones.

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[1] Interview with Traiser, cited on page 62, and Polland, cited on page 66.

[2] Interview with Polland, cited on page 66.

[3] Interview with Traiser, cited on page 62, and Polland, cited on page 66.

Breaking the total number of air travelers using ground transportation to and from Midway Airport into geographic groups, we find the relative mode popularities in terms of percentages as shown in Table II-2 (184).

The figures in Table II-2 are for a mid-summer weekday. It may be added that of air travelers using the private automobile for transportation to and from Midway, only 10% originated and terminated trips within a two-mile radius of the intersection of State and Madison Streets.

The average air passenger occupancy of cars parked in terminal parking lots at Midway Airport on a weekday in 1957 was 1.3. The duration of parking times in terms of percentages of cars parked for those times is as follows (185):

| Duration of Parking | Percent of Cars Parked |
|---|---|
| Less than 1 1/4 hours | 56 |
| 1 1/4 to 3 1/4 hours | 21 |
| 3 1/4 to 6 1/4 hours | 3 |
| 6 1/4 to 12 1/4 hours | 9 |
| More than 12 1/4 hours | 11 |

Air travelers storing their automobiles at Midway Airport for the duration of air journeys leave them an average of 1.9 days. Automobile-using air travelers who are deposited or picked up at the Midway terminal with no concomitant parking comprise about 40% of all automobile-using travelers. The average stopping or standing time consumed by the

TABLE II-2

Airport Transportation Mode for Different Local Origins and Destinations

| | ORIGINATING PASSENGERS USING | | | |
|---|---|---|---|---|
| ORIGIN AREA | PRIVATE AUTO | TAXI | AIRPORT LIMOUSINE | OTHER |
| CBD | 9% | 48% | 40% | 3% |
| Near North Side | 20% | 64% | 15% | 1% |
| North Side | 46% | 38% | 13% | 3% |
| South Side | 56% | 35% | 3% | 6% |
| North Suburbs | 68% | 13% | 13% | 6% |
| South Suburbs | 78% | 16% | 1% | 5% |
| Outside Metropolitan Area | 64% | 15% | 5% | 16% |
| | **TERMINATING PASSENGERS USING** | | | |
| CBD | 6% | 40% | 53% | 1% |
| Near North Side | 11% | 55% | 32% | 2% |
| North Side | 40% | 43% | 14% | 3% |
| South Side | 39% | 45% | 9% | 7% |
| North Suburbs | 60% | 14% | 19% | 7% |
| South Suburbs | 71% | 17% | 4% | 8% |
| Outside Metropolitan Area | 68% | 7% | 13% | 12% |

vehicles serving this 40% is 2 minutes. Although only about 10% of drivers entering or leaving Midway on any given weekday report parking for one day or longer, there is a heavy accumulation of parked duration-of-trip cars which amounts to 35% of all vehicles parked on that given day. Table II-3 gives the percentages of cars parked for various visit purposes at Midway Airport (185):

TABLE II-3

Percentage of Cars Parked at Midway for Various Purposes

| Purpose of Visit | Percent |
|---|---|
| Transport air passengers | 74 |
| Transport business visitors | 10 |
| Transport sightseers | 11 |
| Transport employees | 5 |
| Transport others | 0 |

Table II-4 lists the average number of hours passenger cars were parked for various visit purposes on a weekday at Midway (185):

## TABLE II-4

### Average Time Cars Are Parked at Midway for Different Purposes

| Purpose of Visit | Average Hours Parked |
|---|---|
| Transport air passengers to and from airport without duration-of-trip parking | 1.0 |
| Transport air passengers, duration-of-trip parking | |
| Less than one day | 10.7 |
| More than one day | 45.6 |
| Transport others | |
| Employees | 6.5 |
| Sightseers | 1.2 |
| Business visitors | 1.1 |
| All purposes | 1.9 |

The Taxicab. Tables have already been given showing the relative popularity of the taxicab among ground-traveling air passengers from various parts of the Chicago Metropolitan Area bound for Midway Airport. It seems to be the most frequently-used mode for passengers originating and terminating trips on the near North side, for passengers originating in the CBD, and for passengers terminating in other parts of the city. It is least frequently used among suburban passengers. It received 55% of its air passenger patrons from the area

within a two-mile radius of the intersection of State and Madison Streets. It is also the most popular mode used by air passengers in reaching an airport limousine boarding station and in leaving an airport limousine debarking stop away from the airport itself. Originating passengers bound for Midway and using taxicabs to reach limousine embarkation points number 35.4% of the total of passengers (originating) using limousines. (Walking, the next most popular mode, claims 29.8%.) Terminating passengers leaving Midway by limousine and taking taxicabs from limousine debarkation points number 54.7% of the total of terminating passengers using limousines (184).

Taxicab fares in the city of Chicago are 35¢ for the first one-quarter of a mile and 10¢ for each additional two-fifths of a mile. Each additional passenger costs 20¢. Waiting is charged for at the rate of 10¢ for every three minutes or fraction thereof. Hand baggage is carried free. Trunks are charged for at the rate of 25¢ each.

Distances generally given are 12 miles from the CBD to Midway, 17 miles from the CBD to O'Hare. The Checker Cab Company gives the distance from the intersection of State and Madison Streets to Midway as 11 miles.[1] American Airlines gives the distance from the intersection of State and Madison Streets to O'Hare as 23 miles.[2]

Travel time from the intersection of State and Madison Streets to O'Hare is given by the Yellow Cab Company as 1 1/2 hours.[3] This may

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[1] Personal interview with representative of Checker Taxi Company, Chicago, Illinois, August 12, 1960.

[2] Personal interview with representative of the Chicago Office of American Airlines, Chicago, Illinois, August 12, 1960.

[3] Personal interview with representative of Yellow Cab Company, Chicago, Illinois, August 12, 1960.

be taken as a conventional "allow for" figure, and the actual running time seems to be from 45 minutes to an hour at most times on most days. The Checker Taxi Company gives the travel time from the intersection of State and Madison Streets to Midway as about 35 minutes.[1] A figure of 40 minutes is usually given by other sources for this run. It must be remembered that these estimates antedate the opening along its full length of the Northwest Expressway, which will cut the running time to O'Hare considerably.

The Checker Taxi Company gives $3.75 as the fare from the intersection of State and Madison Streets to Midway, and the Yellow Cab Company estimates the fare from the intersection of State and Madison Streets to O'Hare as $6.35.[2]

The air passenger loading per vehicle for taxicabs serving Midway Airport is 1.6.

The Airport Bus - Limousine.[3] Figures have already been given on the relative popularity of limousine transportation among ground traveling air passengers as a whole in the Chicago Metropolitan Area, and among such passengers grouped geographically. It may be noted that 69% of originating passengers using the limousine as a mode were from the area within a two-mile radius of the intersection of State and Madison Streets, and 77% of terminating passengers had destinations within this area (184).

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[1] Interview with Checker Taxi Company, cited on page 72.

[2] Interview with Checker Taxi Company, cited on page 72, and Yellow Cab Company, cited on page 72.

[3] In some cities, the vehicle employed for limousine service is a bus (and it is in Chicago). Normally in this report such buses will be referred to as limousines.

Ground traveling air passengers utilizing limousines are almost always making "linked trips"--that is, they are using the limousine for part of their journey to or from the airport, another mode for the rest of it. Table II-5 shows the relative popularity of various modes that are linked with the limousine by passengers being served by Midway Airport (184).

TABLE II-5

Percent of Limousine Passengers Using Various Modes to Connect with Limousine

Originating Passengers--Mode of Transportation to Limousine Boarding Point:

| Mode | Percent of Bus Passengers Using |
|---|---|
| Taxi | 35.4 |
| Private Auto | 9.7 |
| CTA Bus | 2.6 |
| CTA Rapid Transit | 2.6 |
| Train | 3.5 |
| Walking | 29.8 |
| Other | 16.4 |

Terminating Passengers--Mode of Transportation from Limousine Stop:

| Mode | Percent of Bus Passengers Using |
|---|---|
| Taxi | 54.7 |
| Private Auto | 3.2 |
| CTA Bus | 2.6 |
| CTA Rapid Transit | 1.0 |
| Train | 4.7 |
| Walking | 15.8 |
| Other | 18.0 |

Route distances for limousines are approximately the same as for taxicabs. The limousine fare from the Loop to O'Hare Field is $2.25, from the Loop to Midway Airport $1.45.[1] From Midway to O'Hare it is $2.50 (128). Limousine travel times are approximately the same as for taxicabs.

In 1958, the Continental Air Transport Company, Inc., which operates the Chicago limousines, had 194 scheduled round trips daily from the Loop to Midway and O'Hare Fields, averaging more than 8 round trips per hour and carrying 1,272,000 passengers--slightly less than one-third of all airline passengers originating or terminating their flights in Chicago's metropolitan area. In the 10 years between 1949 and 1958, the volume of limousine passengers rose from 584,000 to 1,272,000. This rate of increase was approximately 58% of the rate of increase in scheduled airline passenger arrivals and departures during the same period (89).

For the future, it is expected that in 1965, limousines will carry 1,500,000 to 1,700,000 passengers, 80% originating or terminating in the central area of the city of Chicago. This 80% would amount to 3,333 passengers a day--208 per hour if we assume a 16-hour operating day (89). It is expected that the intensified shifting of passenger traffic from Midway Airport to O'Hare Field will favor the limousine (and the helicopter) at the expense of the taxicab (89).

Congestion in the Chicago CBD caused by the unloading and loading of airport buses is a cause of great concern to city officials, and city

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[1] Interview with American Airlines, cited on page 72.

planners are working on a proposal which will banish by city ordinance limousines from the Loop area.[1] Two-thirds of the more than 30 ticket offices in the Loop area serving scheduled airlines are within one block of the corner of Wabash Avenue and Monroe Street, an area known as "Airline Row". Often three to five limousines (buses) will be parked along Monroe Street between Wabash Avenue and State Street, angled in to the curb in such a way that only two of Monroe Street's four lanes are available for moving traffic. Taxicabs fill in the remainder of the curb space in the block. Unless an air terminal is built (as proposed) on the fringe of the Loop and the limousines required to use it, rather than the Loop area, then it is inevitable that off-street docking facilities in some form will have to provide the solution (89).

The Helicopter. Chicago Helicopter Airways, Inc. (CHA), inaugurated scheduled passenger service between Midway Airport and O'Hare Field on November 12, 1956. In May, 1957, it began its first suburban service to Gary, Indiana--later adding its second suburban service to Winnetka, Illinois. Also in 1957, passenger service between Midway Airport and Meigs Field and between O'Hare Field and Meigs was begun. The line now serves passengers on the Golden Triangle with clockwise and counter-clockwise flights, plus the two suburban runs.

There are 191 CHA flights daily. Of these, 7 are Winnetka/O'Hare/Midway and 8 are Gary/Midway/O'Hare flights. The rest are around the Triangle. There are 2,292 available seats daily, as of August 1, 1960. Scheduled passenger flights begin at 6:10 a. m. and end at 11:24 p. m. (82).

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[1] Personal interview with Mr. Clifford Campbell, Deputy Planning Commissioner, City of Chicago, July 1, 1960.

Present fares are given in Table II-6.

TABLE II-6

Helicopter Fares in Chicago

| | Meigs | Midway | O'Hare | Winnetka | Gary |
|---|---|---|---|---|---|
| Meigs | ---- | 5.00 | 6.00 | 8.00 | 8.00 |
| Midway | 5.00 | ---- | 6.00 | 8.00 | 6.00 |
| O'Hare | 6.00 | 6.00 | ---- | 5.00 | 9.00 |
| Winnetka | 8.00 | 8.00 | 5.00 | ---- | 14.00 |
| Gary | 8.00 | 6.00 | 9.00 | 14.00 | ---- |

In Table II-7 taxicab fares (estimated), limousine (airport bus) fares, and helicopter fares are compared, together with the various travel times for each mode. Limousine times are assumed to be the same as taxi times. It will be seen from this table that helicopter times represent a great saving over the travel times for the other two modes, and that helicopter fares are generally below taxi fares, but still considerably above airport bus fares. The time figures in the table represent minutes. It should be recalled that the helicopter fares are subject to a 10% federal tax, and that a tip in addition to the fare is expected of taxicab and limousine riders (430).

TABLE II-7

Comparison of Helicopter, Taxi, and Limousine Times and Fares in Chicago

| | Midway/ Meigs | O'Hare/ Meigs | Midway/ O'Hare | Midway/ Gary | Midway/ Winnetka |
|---|---|---|---|---|---|
| Helicopter Time | 9 | 11 | 11 | 16 | 21 |
| Taxicab Time | 40-70 | 75-90 | 60-75 | 120 | 120 |
| Helicopter Fares | $5.00 | $6.00 | $6.00 | $6.00 | $8.00 |
| Taxicab Fares | $3.25 | $7.50 | $7.50 | $12.00 | $12.00 |
| Limousine Fares | $1.45 | $2.25 | $2.50 | ----- | ----- |

Except for the between airport trips, Table II-7 is of limited value for comparison because of the particular trip end points used, namely, the helicopter terminals. A more informative analysis would be one which compares time and fares between the airports and the origins or destinations (other than the airports) of the users. Such an analysis would show a materially increased time and fare for travelers using the helicopter as one link in a multi-mode trip to any location other than the helicopter terminal or the other airports. For example, for the trip from Midway to the corner of State and Madison in the Loop, the following comparison might be made:

| Using Helicopter Mode | | | Using Taxi Mode Only |
|---|---|---|---|
| **Time:** | | | |
| Mean waiting time[1] | = | 18 minutes | |
| Flight time | = | 9 | |
| Unloading, baggage pick-up, enter taxi | = | 2 | |
| Taxi to State and Madison Streets | = | 5 | |
| Total trip time | = | 34 minutes | 40-70 minutes |
| **Fare:** | | | |
| Helicopter to Meigs | = | \$5.00 | |
| Taxi--Meigs to Loop | = | .95 | |
| Total trip fare | = | \$5.95 | \$3.75 |

Obviously any analysis of this type which uses only one trip is prejudicial to one system or another. A complete analysis is required (which was beyond the means of the present study) which would compare time and fares of all modes for trips between the airport and all origin and destination points. The point in the example given above is that for the majority of travelers, the helicopter would represent only one link in a multi-link trip (as, indeed, is also true of the limousine). The more appropriate comparison of modes, in terms of times and fares, should be for the total trip. In these terms, the advantages of the helicopter over the taxi and limousine are not so clear-cut. However, the taxi and limousine can do almost nothing to materially reduce the time which they

[1] Mean waiting time is equal to 1/2 median headway.

presently take. The helicopter, on the other hand, can reduce waiting time substantially by decreasing headway when the load factor justifies it; flight time can also be improved somewhat by increasing speed capability. By drastically reducing headway, even with present helicopters, the total time reported in the example above could be cut in half.

During each successive year for the three full-year period that CHA has offered passenger service, it has approximately doubled its number of revenue passengers carried and its number of revenue passenger miles flown over the numbers for the preceding year. Figures for 1960 are not yet available, but indications are that the number of revenue passengers will again have doubled over 1959.[1] Statistics for 1957, 1958, and 1959 are given in Table II-8 (81).

TABLE II-8

Statistics for Chicago Helicopter Service

| | 1959 | 1958 | 1957 |
|---|---|---|---|
| Revenue Passengers | 204,389 | 108,911 | 55,310 |
| Revenue Passenger Miles Flown | 3,667,453 | 1,990,109 | 895,221 |
| Available Seat Miles Flown | 7,233,468 | 5,343,716 | 2,598,989 |
| Passenger Load Factor | 50.7% | 37.2% | 34.4% |
| Revenue Airplane Miles Flown | 819,286 | 695,704 | 568,664 |
| Percent of Scheduled Miles Flown | 93.9% | 95.9% | 92.9% |
| Revenue Hours Flown | 10,639 | 9,585 | 9,050 |

[1] Personal interview with Mr. Clyde O. Sundberg, Superintendent of Stations, Chicago Helicopter Airways, Inc., August 1, 1960.

It is significant to note in Table II-8 that between 1957 and 1958 although the available seat miles flown increased by more than 100%, the passenger load factor increased by only 3.2%, but between 1958 and 1959--when seat miles flown increased by only 40%--the load factor rose by over 35%.

Peak periods in demand are taken care of by the addition of extra sections to scheduled flights. Thus in August, September, and October of 1959, 137,100 extra section miles were flown (84).

The company forecasts that it will fly 10.8 million seat miles in 1960 and 24 million seat miles in 1962 (with the help of the new S-61 helicopters ordered from Sikorsky). It is believed that in 1961 a total of 500,000 passengers will be carried, and that the number will reach 1,000,000 in 1962. The company thinks there will be a good chance of being off direct subsidy in 1962 (430).[1]

CHA now has eight 12-passenger Sikorsky S-58 helicopters in passenger service, two of them added to the fleet in 1960. A conditional order for six 25-passenger, twin-turbine, S-61 helicopters has been placed with Sikorsky Aircraft, delivery on the first four to begin in 1961. Fully equipped, the S-61 will cost about $650,000. The new S-58, fully equipped, costs $280,000. The company expects to gain financially from the increased seating capacity, increased speed, and longer time between overhaul periods for the S-61 over the S-58 (81).

CHA operates its S-58's at an average block speed of 88 m.p.h. The cruising speed of the S-61's is expected to be 150 m.p.h. (430, 84). Present cruising altitude for the S-58's is 1500 feet. Within the control zones of the airports the altitude maintained is 500 feet. In crossing

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[1] Interview with Sundberg, cited on page 80.

airport runways the Federal Aviation Agency regulations permit CHA to operate at an altitude of 300 feet. Under these conditions of altitude the helicopters can move in and out of airports with almost complete freedom from the flight patterns of fixed-wing craft, which eliminates almost entirely any holding periods for the helicopters and enables them to meet their schedule requirements with precision.

Each CHA helicopter is manned by a pilot and a co-pilot, and all flights are by VFR. Even with no IFR capability, almost 96% of its scheduled flights were actually flown. Turn-around time at stops is two minutes on the average.

In the first quarter of 1958, the yield to CHA per passenger seat mile was 32.24 cents. The cost per available seat mile was 36.5 cents (54). In September of 1958, the yield per passenger seat mile was 32.5 cents. The cost per available seat mile was 29 cents (17 cents direct costs, 12 cents indirect costs). By way of comparison, in 1957 local service carriers had average yields of 6.8 cents per passenger seat mile and total costs of 5 cents per available seat mile. The cost/yield ratio of these local service carriers in 1957 was .72. In 1958, CHA's cost/yield ratio was .82, with excellent prospects for a ratio of .70 imminent (29).

The extremely rapid growth of CHA in passenger volume has been due in no small part to its cooperation with the fixed-wing carriers, and theirs with CHA. All major foreign and domestic airlines may ticket passengers on CHA and check passenger baggage through CHA facilities, and CHA may reciprocate. In changing from helicopter to fixed-wing carriers or vice versa, passengers do not have to buy additional tickets or shift their own baggage. In 1959, about 50% of CHA passengers were ticketed by other foreign and domestic lines (81). Several airlines serving the Chicago metropolitan area are investigating the possibility of their

paying half of the helicopter fare on CHA of passengers changing from Midway Airport to O'Hare Field to take turbojets for California (430).

## Future Plans for Airport Transportation in Chicago

The most ambitious proposal for effecting an alteration in airport/metropolitan area travel habits in the Chicago Metropolitan Area that is currently under consideration would establish a combined airline terminal and heliport, with adequate parking facilities, on the edge of Chicago's CBD. This proposal was prepared for the Gateway Committee of the West Central Association, and has the enthusiastic support of the Department of City Planning (89).[1]

The elements of the proposal comprise:

> "1. An airline terminal which would provide a single location in Chicago's Central Area for the consolidation of ticket offices and certain other functions of all airlines operating out of Chicago, as well as an assembly point for all passengers and passenger transportation destined for Midway or O'Hare Airports.
>
> 2. A heliport which would enable the provision of convenient rotary wing service from the Central Business District to Chicago's airports and, in the future, to the airports or heliports of other cities.
>
> 3. Major parking facilities to serve both the proposed new facilities mentioned above..." (89).

The recommended location for the terminal is the block bounded by Madison, Monroe, Canal, and Clinton Streets. Thus the new facility would be across the street from the Chicago and North Western Railway

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[1] Interview with Campbell, cited on page 76.

Station. Much of the CBD would be within easy to reasonable walking distance of the terminal. The heliport would be located within "that area flanking the depressed Northwest Expressway and bounded by Jefferson, Madison and Monroe Streets". (89)

Between the air terminal and the heliport would be a two-level parking garage, occupying an entire block and containing 648 spaces. The roof of the garage will be a landscaped plaza, across which and connecting the terminal and the heliport buildings will be two walkways, covered and utilizing mechanical moving sidewalks. Eventually two additional, six-story garages for parking will flank either side of the heliport and be connected to it by bridges giving access to the walkways. These two garages will hold 3700 cars.

The heliport will accommodate the 25-passenger helicopters which will begin to come into use in the area in 1961. The site has been selected with a view to providing ample unobstructed air space around it for optimum gradual ascent and descent in taking off and landing operations. The heliport will include offices, waiting rooms, ticket and reservation stall space, and taxi bays.

The air terminal--a three-story building--will, on its lower level, provide airport bus loading bays for 16 to 20 buses, mechanized baggage handling installations, and escalators to the main floor of the terminal above. The main floor, on Canal Street, will have taxi bays, waiting areas, lounges, ticket and reservation booths, check-in counters, restaurants, and concessions.

In planning this air terminal/heliport facility, much use has been made of grade differences within the area. It is contemplated that the present street level will serve the planned facility and the North Western

Railroad Station, while through traffic and some local traffic will be routed onto an upper level, thus alleviating much congestion.

Also to be noted is the fact that the proposed air terminal/heliport facility will be located at the confluence of three great expressways now or soon to be built--the Congress, the Northwest, and the South. Yet it will be far enough from them so that it is believed no serious backing up of traffic on the expressways will be caused by their serving the facility.

The airline terminal cost estimate is $4,494,000. The heliport cost estimate is $2,485,500. The parking garage cost estimate is $2,582,000. The re-use value of the cleared land is estimated at about $1,994,000. The total estimated cost of the facility will be $11,555,500 (89).

It is the hope of the Department of City Planning that when the facility is completed the ordinances of the city of Chicago will be amended to ban airport bus and limousine traffic from the CBD, requiring such services to use the new facility as their terminus.[1] It is further hoped that the airlines may underwrite part of the expense of the project.

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[1] Interview with Campbell, cited on page 76.

# Chapter 2. Airport Transportation in the San Francisco Bay Area

## The San Francisco Bay Area

The San Francisco Bay Area is generally considered to comprise the nine counties of Alameda, Contra Costa, Marin, Napa, San Mateo, San Francisco, Santa Clara, Solano and Sonoma; the population of this area in 1960 was approximately 3,750,000.

Population growth for the area has been forecast as follows (426):

| Year | Bay Area Total |
|---|---|
| 1960 | 3,752,000 |
| 1970 | 4,314,000 |
| 1980 | 5,729,000 |
| 1990 | 7,425,000 |
| 2000 | 8,261,000 |
| 2010 | 11,260,000 |
| 2020 | 14,410,000 |

Thus, an approximate doubling of present population within the next 30 years and a quadrupling within the next 60 years are forecast. The smallest increase is predicted for San Francisco County, which, according to the 1960 census, actually lost 30,000 people in the previous ten-year period.

Six counties contain the major population concentrations:

| County | Some Principal Communities | Population |
|---|---|---|
| Alameda | Berkeley<br>Oakland<br>Alameda<br>San Leandro | 954,000 |
| Contra Costa | Walnut Creek<br>Richmond<br>Concord | 396,000 |
| Marin | San Rafael | 152,000 |
| San Francisco | City and County are coterminus | 743,000 |
| San Mateo | South San Francisco<br>Millbrae<br>San Mateo<br>Belmont<br>Redwood City<br>Menlo Park | 441,000 |
| Santa Clara | San Jose<br>Palo Alto<br>Sunnyvale<br>Santa Clara | 657,000 |

There are 6,958 square miles of land within the nine counties. In 1959 about 616 square miles were urbanized; it is predicted that this will increase to 1295 square miles by 1990 and 2389 square miles by 2020.

Air transportation needs of the Bay Area are presently served at three airline airports--San Francisco International, Metropolitan Oakland

International, and San Jose Municipal. In addition, two flights daily in each direction stop at Santa Rosa.

## Airports Serving the San Francisco Bay Area

San Francisco International. San Francisco International is by far the busiest of the three airports. It is situated in San Mateo County, in the city of Millbrae, some 13 miles southeast of downtown San Francisco, served by a direct interchange from the Bayshore Freeway, which connects most of the important peninsula communities between San Francisco and San Jose. This facility now ranks fifth among the 22 large-hub airports of the United States in passenger volume, serving about 3.5% of the total passengers carried on scheduled domestic airlines in the United States. Service is provided by 13 scheduled air carriers. Some 5,017,479 scheduled air carrier passengers (enplaned and deplaned) used the airport facilities during the fiscal year 1959-1960--an average of nearly 14,000 per day. This was a 17.3% increase over the previous fiscal year and double the traffic of six years before.

Scheduled airline arrivals and departures during the fiscal year amounted to 146,307 movements, or 420 per day during June 1960--an increase of 12.2% over the previous year. There were 39 scheduled jet air carrier takeoffs daily in June, 1960. Frequent service is available to Europe, the East Coast, Middle West, South America, Hawaii, and the Pacific Region and the Orient.

A large and steady growth of passenger travel is forecast well into the future; the airport management anticipates that total passenger movements (arrivals and departures) will approximate 8,400,000 by 1970. Federal Aviation Agency studies predict between 4.2 million and 4.7

million enplaning passengers per year by 1970; the upper and lower limits depend upon the amount of diversion to the Oakland and San Jose Airports that may take place. Ultimate capacity of the airport is planned to be 10,000,000 passengers per year, plus a vast predicted increase in the amount of air mail, air freight, and air express handled.

In addition to the passengers there is an undetermined number of visitors who must total into the hundreds of thousands or possibly the millions every year. In addition, 12,500 people are employed at the airport during a 24-hour period, of whom over 10,000 work at the maintenance facilities of United Air Lines.

The master plan for the terminal area, prepared by Welton Becket and Associates, Architects - Engineers, calls for extensive additional terminal building construction during the next decade to handle the predicted passenger and visitor growth, with construction of the South Terminal addition scheduled to start in the spring of 1961, adding 14 gate positions to the present 19, and with a master plan providing for 62 gate positions by 1970. The availability of vacant land for expansion and development of airport-related activities indicates that the number of individuals employed at the airport will also increase in the future. Present investment in the airport by the city amounts to $55,500,000, with an additional $35,000,000 investment by the various tenants, and large past contributions by the federal government.

Metropolitan Oakland International. Metropolitan Oakland International is the second largest of the three airports. It is located in Alameda County, some nine miles southeast of the Oakland central business district, and a short distance from the Eastshore (Nimitz) Freeway. This facility is currently being expanded and modernized, with construction of new

runway facilities nearing completion and a new terminal building being started. Revenue passengers enplaned (not including deplaned) have averaged about 150,000 per year in recent years. At one time over 15% of all Bay Area passengers used this airport; this has now declined to less than 7%, but it is felt that traffic volume could return to 15% again by 1970. The East Bay population (Alameda and Contra Costa Counties) of 1,350,000 in 1960 should rise to well over 2,000,000 by 1970; thus there is already a population much larger than that in many other metropolitan areas now receiving far better scheduled air carrier service than does Oakland. There is considerable supplemental air carrier traffic offering low fare flights to Chicago, New York, and Honolulu.

San Jose Municipal. The third airline airport, San Jose Municipal, is located on the north side of the city of San Jose, about five miles from the central business district, and not far from the intersection of the Bayshore and Eastshore Freeways. San Jose is the county seat and largest city of Santa Clara County, the fastest growing county in the Bay Area, with a predicted population of at least 1,300,000 by 1970. Air travel has been rising steadily, with enplaned passengers totaling 22,568 in 1957 and predicted to go to from 100,000 to 177,000 by 1970.

Present airline service is provided by one feeder carrier; this city is now the largest feeder stop in the United States. Principal destination of air travelers from San Jose is Los Angeles (two non-stop flights daily in each direction, plus several flights with intermediate stops).

With the improvements in airline service and equipment to keep pace with growth and demand, and the important interrelationships between the electronics and space technology industries of Santa Clara County and Southern California, long-term growth of air travel at this airport should be almost certain.

Thus it is evident that each of these three airports serves a somewhat different function, while together they are (or soon will be) indispensable components of a total airport complex serving the Bay Area. San Francisco International is the principal airport for all of northern California. It serves the hub city of San Francisco, one of the major centers of business activity in the United States, and also the Peninsula area of San Mateo and northwestern Santa Clara Counties, with a high-average income population and one of the nation's major concentrations of advanced technology industries, clustering around Stanford University. This airport also draws heavily upon the East Bay communities including both the lower average income population employed in heavy industry and also the scientific and other intellectually based activities clustered in and around the University of California. It is known that people from as far as Sacramento, about 100 miles distant, drive to San Francisco to enplane for long flights. A large part of the dominant importance of San Francisco is related to the present patterns of geography, land use, income distribution, and business location. Some of the activity also represents the results of a very aggressive and forward looking airport development program; this has probably attracted more passengers than would have been the case if Oakland and San Jose had been developed equally aggressively.

The future increase of traffic at Oakland will probably be partly the result of the availability of new and attractive facilities, partly due to growing adjacent population, and in good part by the fact that runway and airspace limitations will force some redistribution of aircraft landings and takeoffs away from San Francisco International.

The San Jose Airport traffic will probably grow for similar reasons. There will be particular emphasis on travel to southern

California, for a significant travel-time saving can be provided to travelers to and from the lower Peninsula communities. They can reach this airport in the same ground travel time as in going to San Francisco International, or less than that, but are then some 35 miles closer to Los Angeles, at an airport which should be able to accommodate commuter type traffic with less problems of parking, walking, congestion, etc., due to the smaller scale of the operations there.

The foregoing serves as a background for the discussion that follows of the ground transportation to and from the three airports in the San Francisco metropolitan area. The matter of ground travel to and from two of them--Oakland and San Jose--can be disposed of quickly. Apparently little or no information is available on the origins and destinations of passengers, visitors, and employees going to and from these two facilities.

## Airport Transportation in the San Francisco Bay Area

Metropolitan Oakland International. At Oakland most travel to and from the airport is by private automobile. Other available transportation includes taxis, limousine service to downtown Oakland (40 minutes, $1.25) and local bus service. The local bus service is provided by the Alameda-Contra Costa Transit District. One of its routes starts at the airport and ends in East Oakland (98th Avenue and MacArthur Boulevard); travelers to and from the central areas of Oakland would have to change buses. Service is provided every 20 minutes from 6:40 a. m. to 8:40 a. m. and from 2:40 p. m. to 5:55 p. m.; from 8:40 a. m. to 2:40 p. m., and from 5:55 p. m. to 8:00 p. m., every 40 minutes. The transit district does not seem to have any figures showing how many of the people using this line embark and debark at the airport.

San Jose Municipal. San Jose Municipal airport, similarly, is reached primarily by automobile. There is no limousine service. San Jose taxi service is available. Public transportation is provided by buses of the San Jose City Lines, operating every 25 minutes from 6:10 a. m. to 9:45 a. m., and every 30 minutes thereafter until 6:45 p. m. at a 10¢ fare. An official of the bus company stated that patronage was the poorest of any of their routes.

There appeared to be no indication of any substantial change in ground transport service to either of these two airports that could be anticipated in the foreseeable future.

The remainder of this discussion will be focused upon the third facility, the airport at San Francisco.

San Francisco International. In the discussion that follows the reader should note carefully the distinction between the terminal area--the focal point for passenger and visitor traffic--and the other areas of the airport complex such as the maintenance bases, where most of the airport employment takes place.

Principal mode of ground transport to the airport is the private automobile. A survey conducted during the 12-hour period (11 a. m. to 11 p. m.) on August 22, 1958 showed that 78% of all persons entering the terminal building (2,068 during the peak hour, 8 to 9 p. m.) arrived by this means, while 16% arrived by bus or limousine and 6% by taxi. Transportation for all employees at the airport was probably even more automobile-oriented, as these individuals would not frequently use limousines or taxis. During the 12-hour survey period, 8,321 vehicles entered the terminal area, with 945 during the peak hour of 6 to 7 p.m.;

the maxima, occurring during different hours of the 4 to 8 p. m. period, was 799 private cars, 68 taxicabs, 77 trucks, 23 buses, and 8 limousines per hour.

Parking in the terminal parking lots ranged from 1,950 to 2,344 vehicles during the 12-hour period of the survey; no figures are available on employee parking lots in other parts of the airport. The 1960 terminal area parking facilities have a capacity of 3,000 vehicles. Immediate additional capacity for 800 vehicles and expansion to 6,000 in the near future is planned. The airport management hopes to add to the terminal complex an 8,000 car capacity multiple-deck parking structure built by private investment not later than 1965.

A limousine (bus) service operated every 20 minutes from 6:00 a. m. to 10:00 p. m. and scheduled according to flight departures from 10:00 p. m. to 5:30 a. m. connects the airport with a specially built downtown San Francisco limousine terminal, 13 miles away, at a $1.20 fare. Travel time is usually 25 or 30 minutes except during the morning and evening rush hours, when it may take as long as an hour. During the survey period (11 a. m. to 11 p. m.) on August 22, 1958, 55 limousines arrived, carrying 1,013 passengers, and 50 departed carrying 975 passengers. Peak hour traffic to the airport occurred between 5 and 6 p. m. with 227 passengers traveling in 8 limousines and peak hours to San Francisco were 7 to 8 p. m. and 9 to 10 p. m., with 117 passengers in 4 limousines during each of these periods. Average load during the study period appeared to be 28 arriving passengers per limousine and 29 departing passengers per limousine.

A significant number of trips to San Francisco are made by taxi, with 210 taxis departing carrying 395 passengers during the 12-hour study period. The fare of about $7.00 to downtown San Francisco is less significant with so many taxis being shared by more than one person.

An infrequent limousine service is operated down the Peninsula, with six trips per day, all of which terminate at Palo Alto except for one southbound to San Jose and two northbound from San Jose each day. Taxi service is also used to Peninsula points; while the cost is substantially higher often informal rider groups are formed at the taxi stand by people traveling in this direction, making sharing of the fare possible.

Mass transportation at the airport is provided by Western Greyhound Lines, which operates an extensive network of local bus routes in the San Francisco Bay Area. The airport is a stop on a route between the downtown San Francisco Greyhound Terminal and Redwood City, from which point connecting buses proceed through Menlo Park, Palo Alto, etc. to San Jose. The first bus in the morning passes through the airport at 5:12 a. m., the last at 2:20 a. m. Frequency of service varies from a maximum of one every 10 minutes at morning and evening peak hours, one every 20 minutes during most of the day, every 30 minutes during the evening, to one every 40 minutes after 10 p. m.; there are 66 northbound and 72 southbound buses every weekday. No figures on patronage were obtained, though it was said to be only a few individuals on each trip and the writer, who frequently uses the service by choice has never noticed very heavy usage to or from the airport.

An alternative mass transit facility runs near the airport in the form of the railroad commuter service of the Southern Pacific Company,

with a station at Millbrae, about two miles distant. Some 14,000 daily passengers use these trains, of which 17 in each direction stop at Millbrae every weekday out of the total of 29 operated. Transportation from Millbrae to the airport would have to be by taxi, and it is suspected that there are probably few individuals who choose this route.

Available information on origins and destinations within the Bay Area of passengers, visitors and employees traveling to and from the airport is meager. The August 22, 1958 study showed origins of passengers who enplaned at the airport during the 12-hour study period to be as follows, based on a 73% sampling conducted by airline stewardesses on all scheduled flights leaving that day (145):

TABLE II-9

Origins of Enplaning Passengers at San Francisco International

| County of Origin | Percent Distribution by Bay Area County |
|---|---|
| Alameda | 13.8 |
| Contra Costa | 1.8 |
| Marin | 2.0 |
| Napa | 0.4 |
| San Francisco | 56.4 |
| San Mateo | 11.6 |
| Santa Clara | 11.0 |
| Solano | 2.3 |
| Sonoma | 0.7 |

A total of 4.4% of all the passengers surveyed were from outside the Bay Area; the above Bay Area percentages thus represent 95.6% of the total enplaned passengers.

It is estimated by airport officials that more than 10,000 of the employees at the airport, or 76% of the total payroll, are residents of San Mateo County; this is based on 1959 employment levels and percentage figures compiled during a survey conducted in 1956.

A small amount of additional pertinent statistical information was collected during this 1958 study:

(1) Air traveler volume during airline passenger peak hour (8 to 9 p. m.) totaled 1,359, with 655 enplaned, 685 deplaned, and 19 transit.

(2) Aircraft average loads during peak hour (this was prior to jet operation) arriving aircraft--44 passengers/aircraft; departing aircraft--53 passengers/aircraft.

(3) Aircraft operations during peak hour: 15 in, 13 out, 28 total.

(4) Taxis entering terminal area during peak hour of taxi operation, 68.

It is known that additional statistical information on some phases of the airport ground transport at San Francisco International has been collected by the management of the airport, its consultants, the State Division of Highways, and the airlines. Apparently some of this information has not been processed into a form that would be meaningful to this study, and other data are not presently made available outside the airport management for policy reasons. For example, it is known that data have been collected recently for planning of future vehicular traffic facilities in the terminal complex area; it is also known that an origin and

destination study of people employed at the airport has been conducted, and it is understood that more recent passenger origin and destination studies have also been made.

Future Plans for Airport Transportation at San Francisco International

The plans of the airport management for enlargement of automobile parking facilities at the airport have already been mentioned. A discussion of the future development of ground transport facilities to and from the airport must also include as an indispensable topic the proposed regional rapid transit system now being planned. These plans have been evolving during most of the past decade and a historical review, while interesting, is not too significant to this analysis. The present status and possible future developments are very important, however.

The San Francisco Bay Area Rapid Transit District (BARTD) "has been directed by the Legislature to develop high-speed regional rapid transit for the Bay Area." At present its geographic scope in this regard is limited to the five counties of Alameda, Contra Costa, Marin, San Francisco, and San Mateo. By the summer of 1960, plans had been developed for a proposed 98-mile double track regional rapid transit system that would involve initial capital costs now estimated to be $926,044,000 for the District, plus an additional $127,191,000 to be secured from other sources for construction of a trans-bay tube. These figures are for a fixed plant, do not include cost of rolling stock, and allow for inflationary cost increases up to an assumed rate of completion of construction of December 31, 1966. Capital costs would be raised through additional taxes levied within the District, with operating revenues used to meet all operating expenses, as well as, apparently, debt service on rolling stock.

As a general obligation bond issue would be required to finance the plan, a proposal to issue these bonds and build this system must be submitted to the voters in the five-county area for their approval. This apparently will not be possible before late 1961 or sometime in 1962, thus completion of construction could not occur before 1967 or 1968; this in turn throws doubt upon the estimated capital cost, which provides for possible construction cost increases only through 1966. There is controversy in the Bay Area as to whether this proposed system has any hope of voter acceptance; it is, of course, impossible even to surmise what the outcome may be.

Present plans of the BARTD for its Peninsula Line propose service connecting downtown San Francisco with Redwood City and possibly Menlo Park or Palo Alto; the tracks would parallel the present Southern Pacific railroad tracks from San Bruno (between the airport and San Francisco) southward. Trains would operate at speeds averaging at least 45 miles per hour including time for station stops, and at maximum speeds of 75 to 80 miles per hour, with headways as short as 90 seconds. In off-peak periods service would be less frequent, every five minutes during some periods, down to every 15 minutes at quieter times of the day. The line would have the capacity to move at least 30,000 seated passengers per hour in each direction. Rolling stock would be lightweight and of advanced design, operating fully automatically, with a system of fare collection by electronically-sensed credit cards and monthly billings. It would be unlike any rapid transit system now in operation anywhere in the world.

As far as service to San Francisco International Airport is concerned, the route as presently planned places the tracks at least a mile

from the airport terminal area, with the proposed transit station somewhere in Millbrae perhaps two miles away. No mention is made in the published BARTD engineering reports of service to be provided to airport travelers; as a matter of fact, no mention is made of the airport at all. Perhaps a shuttle bus service would be instituted between the terminal and a nearby transit station although experience at Logan International Airport in Boston with such a service has not been very successful. Discussion with both airport and transit officials brings up mention of a "carveyor system", some sort of arrangement of small moving cars on an endless belt, operating between the terminal building and the transit system line, either at the proposed Millbrae station or a new one nearer. Both parties disclaim any intention of providing the capital funds that would be required for its construction and offer no ideas as to how else this might be done. The transit district apparently feels that it could not alter the route of its main line to run past or under the terminal complex as this would involve too much additional capital cost for construction, and would increase operating time for all trains on the Peninsula line by a couple of minutes due to the somewhat greater length of the route and the possible additional stop.

It is clearly evident, therefore, that the BARTD proposal, which is supposed to link together many of the most significant passenger origin and destination points in the five-county service area, does not plan to include the major regional airport within the scope of its proposed service. This is true even though that airport already averages 14,000 passengers in and out per day with origins and destinations which, according to available evidence, are in large part within the proposed transit service area. In addition, there are the 13,000 employees and uncounted

number of visitors, most of whom also live within the five-county district. The fact that it is predicted that airport passenger volumes will almost double by 1970, only a short while after the 1968 date that appears to be the earliest that the transit trains can reasonably be expected to start running, does not seem to strengthen the present case for airport rapid transit service.

The reasons for this significant omission thus appear to be that on the part of the Bay Area Rapid Transit District there is an unwillingness to commit itself to additional construction and operating costs at a point in the development of its plans when it is involved in reducing the amount of money for which it will have to seek the approval of the voters. There is no direct evidence available to show that the airport management does not desire regional rapid transit service to its terminal buildings. The plan of the airport is to greatly expand revenue from parking in the future by increases in parking fees and by a very large increase in parking facilities in the form of an expensive multi-deck structure. This structure would be built by private enterprise and would presumably require protection of the planned investment by some sort of guarantees of continued long-term demand for large scale parking. The airport management appears convinced that the public, in fact, desires to come to the airport by automobile, and supports this belief by the statistics showing the overwhelming present use of this mode. The fact that for most passengers there is at present no satisfactory alternative is not given too much weight in developing this point of view.

On the other hand, it must also be clearly recognized that the airport management is placed in a difficult position by its desire to serve the public with a continuing high standard of service. The demand for

automobile parking at the airport exists now, to the point of saturation, with demand that shows every sign of continuing to grow well into the future. The contractual obligations it has to service its bonds must also be considered; all these factors tend to combine to produce the automobile orientation of management. Whether either understandings or conflicts concerning rapid transit service to the airport exist at a higher political level is information that is not presently available.

## Chapter 3. Airport Transportation in New York City[1]

### The New York Metropolitan Area

New York City, composed of the boroughs of the Bronx, Kings, Queens, New York, and Richmond, had a total population of 8,050,000 in 1955 and a predicted population of 8,400,000 in 1975 (355). Similar population figures for the remainder of the 22-county metropolitan region are 7,175,000 in 1955 and 10,700,000 predicted for 1975. Hence, the total population of the New Jersey-New York-Connecticut metropolitan region was 15,225,000 in 1955 and predicted to be 19,100,000 in 1975. These figures predict only a 4% increase in the New York City population over the 20-year period and a 49% increase in the population of its environs over the same time period.

The area of intensively developed land is expected to increase from 1,100 square miles in 1955 to over 1,800 square miles by 1975, and the employment of the area will increase by 1 1/2 million in the same time period.

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[1] A number of excellent studies have been conducted in the New York area which are concerned, in whole or in part, with airport transportation or closely related matters. The scope of the present report does not permit a recapitulation of even a significant portion of the available material nor would a useful purpose be served by doing so in that many of these studies have been fairly widely-distributed. Of particular value is the Port of New York Authority's "New York's Domestic Air Travelers, November 1955 through October 1956" which, in large measure, adequately performs the function of the present section. Our purpose, therefore, is only to highlight the most significant facts from the standpoint of the special interests of the present study.

The population in the five core counties (Hudson, New York, Bronx, Kings, and Queens) is expected to remain at approximately 7.5 million, while the "inner ring" counties (Richmond, Union, Essex, Bergen, Passaic, Westchester and Nassau) and the remaining "outer ring" counties are expected to gain by two million each. It is anticipated that well over half of these people will settle in one-family homes in the southern counties of Long Island and New Jersey.

## Airports Serving the New York Area

The New Jersey-New York-Connecticut metropolitan region is served commercially by three major airports: LaGuardia Field, New York International (Idlewild), and Newark Airport.

LaGuardia Field. Located 8.5 miles northeast of mid-Manhattan in the Borough of Queens, LaGuardia Field is served by seven domestic airlines. No scheduled foreign airlines or exclusively cargo airlines use LaGuardia Field (306). Approximately 200 flights arrive and depart from LaGuardia Field per day; hence, nearly 400 scheduled operations are conducted each day. Passenger departures from LaGuardia Field during the year, from November 1955 through October 1956, totaled 2,506,000--or an average of 7,000 per day. The Port of New York Authority predicted an increase of originating and terminating trips at New York airports from 9.5 million in 1955 to 21 million in 1965 and 38 million in 1975 (328). Even though the majority of the increase will go to New York International Airport because of the increased use of jet planes, the total number of trips originating and terminating at LaGuardia Field could be expected to approach an average of 20,000 per day if suitable facilities were provided. In addition to these passengers passing through the airport, several thousand airport workers and visitors travel to and from the airport every day.

Newark Airport. This airport, located west of the Hudson River some 13 miles southwest of mid-Manhattan, is served by 11 scheduled passenger airlines as well as 5 scheduled cargo carriers. Currently, a total of 173 aircraft arrive per day at Newark Airport (306). A total of 1,042,000 passenger departures were reported for the period from November 1955 to November 1956; hence, an average of about 3,000 passengers left Newark Airport per day. According to the traffic predictions previously reported, the daily average total of trips originating and terminating at this airport could increase to 5,000-6,000 by 1965. In addition, several thousand airport workers and visitors also travel to and from the airport each day.

New York International Airport (Idlewild). Of the three major airports in the New York metropolitan area, New York International is the newest and busiest. Located about 15 miles southeast of mid-Manhattan in the Borough of Queens, Idlewild Airport is served by 25 domestic carriers and 14 overseas carriers. Started in 1947, Idlewild is scheduled for completion in 1970. The total airport area is 4,900 acres, 622 of which are occupied by the "terminal city" area. About 400 domestic flights arrive at or depart from Idlewild during an average day (306). In addition, all overseas flights to New York and the majority of the scheduled cargo flights operate from Idlewild. All jet flights to New York also are directed into and out of Idlewild. The departures from Idlewild during the year from November 1955 to November 1956 totaled 1,422,000 passengers; hence, departures and arrivals approached 3,000,000. In 1959, there were 214,298 airplane movements and 7,000,000 passengers used the airport. The total number of passengers may reach 8,000,000 in 1960, and it is predicted that 12,000,000 passengers annually

will use Idlewild by 1965. Hence, an average of about 600 flights carry 20,000 passengers in and out of Idlewild every day. In addition to these passengers, thousands of visitors and 22,000 airport employees travel to and from the airport each day.

## Airport Transportation in the New York Area

The preceding statistics indicate that approximately 75,000 passengers and employees, together with uncounted thousands of visitors, travel to or from the three major airports in New York every day. The means by which these people reach the airports include rapid transit, taxi, limousine, automobile, and helicopter. The rapid transit availability is very limited and, in the case of two of the airports, passengers using this mode must complete their ground trips by bus. LaGuardia passengers may take the IRT to the 74th Street station on the Queen Line, or the IND to the Roosevelt station and, from either of these stations, complete the trip by bus. Idlewild passengers may take the IND to the Kew Gardens station, or the BMT to the 121st Street station and then complete the trip by bus. Helicopter service is provided to, and between, each of the three major airports from White Plains, Stamford, and Teterboro Airports.

The 1956 survey made by the Port of New York Authority showed that the following percentage distribution of passengers existed among the various transportation modes (328):

TABLE II-10

Airport Transportation Modes at New York Airports

| Mode | LaGuardia | Idlewild | Newark | All |
|---|---|---|---|---|
| Auto | 37% | 42% | 46% | 41% |
| Taxi | 41% | 26% | 12% | 28% |
| Limousine | 20% | 31% | 38% | 28% |
| Other | 2% | 1% | 4% | 3% |

The above figures do not include the transfer passengers, but only one-fifth of all transfer passengers shuttle between airports, and more than half of those used limousine or bus. At the time of the survey (1956) helicopters accounted for fewer than 1% of the passengers. However, for passengers shuttling between airports it was found that helicopters carry 12% of all business passengers and 4% of the shuttling passengers on personal trips. The rapid rise of helicopter service since its inception indicates that the current figures for the helicopter patronage is considerably higher than that quoted above. The 1956 survey revealed that one-sixth of the Manhattan passengers going to Idlewild used automobiles, as did one-eighth of the Manhattan passengers going to LaGuardia and one-tenth of the Manhattan passengers going to Newark Airport. Also, two-thirds of the passengers starting from places other than Manhattan used automobiles to get to all three airports. Limousines were found to carry 70% of the passengers from Manhattan to Newark, and taxis accounted for 43% of the passengers traveling from Manhattan to LaGuardia.

The ground travel time and cost to airline passengers vary greatly with the mode of transportation used. The time and cost figures for limousine service to the CBD are 45 minutes and $1.35 from Newark; 60-75 minutes and $1.50 from Idlewild; and 55 minutes and $1.50 from LaGuardia. Also, the time and fare for limousine service between LaGuardia and Idlewild is given as 40 minutes and $1.35 (306). One source lists the times and costs for taxi service to the three airports given here in Table II-11 (447):

TABLE II-11

Time and Fares for Airport Taxi Service in New York

| | Idlewild | LaGuardia | Manhattan | Newark |
|---|---|---|---|---|
| Idlewild: | | 23 minutes<br>$3.40 | 32 minutes<br>$4.10 | 65 minutes<br>$18.88 |
| LaGuardia: | 23 minutes<br>$3.40 | | | 60 minutes<br>$12.00 |
| Manhattan: | 32 minutes<br>$4.10 | | | 37 minutes<br>$9.00 |
| Newark: | 65 minutes<br>$18.00 | 60 minutes<br>$12.00 | 37 minutes<br>$9.00 | |

The trip times required by private auto will be equal to, or greater than, those listed above for taxi service. Current helicopter fares are presented in Table II-12 (306):

TABLE II-12

Helicopter Fares in New York

| | Wall St. | LaGuardia | Idlewild | Newark | Teterboro | White Plains |
|---|---|---|---|---|---|---|
| LaGuardia.. | $5.00 | | | | | |
| Idlewild.... | $7.00 | $4.09 | | | | |
| Newark.... | $6.00 | $8.64 | $8.64 | | | |
| Teterboro.. | $6.00 | $5.45 | $8.64 | $8.64 | | |
| White Plains | $8.86 | $7.73 | $8.18 | $8.86 | $8.86 | |
| Stamford... | $9.09 | $7.95 | $8.18 | $9.09 | $9.09 | $5.45 |

Many airlines are now featuring joint fares in which they pay for part of the passenger's helicopter fare.

Surveys revealed that almost half of New York's air passengers reside in the New York Metropolitan Area (328). Approximately 88% of the passengers departing from LaGuardia Airport were found to begin their trips from east of the Hudson River, with 53% starting from Manhattan. Approximately 88% of the Idlewild passengers also started their trips from points east of the Hudson River, and only about 50% of the Newark passengers started from east of the Hudson. Table II-13 shows the distribution of origins (by county) of departing passengers at three airports in New York.

TABLE II-13

Origin of Passengers
Departing by Air From Three New York Airports
(Percent of Total Passengers)

| Origin | LaGuardia | Idlewild | Newark |
|---|---|---|---|
| Metropolitan Area | 95% | 94% | 93% |
| East of Hudson | 88 | 88 | 50 |
| Manhattan | 53 | 47 | 38 |
| Bronx | 3 | 4 | 2 |
| Brooklyn | 6 | 10 | 3 |
| Queens | 8 | 9 | 2 |
| Nassau | 9 | 10 | 1 |
| Suffolk | 2 | 1 | 1 |
| Westchester | 5 | 4 | 2 |
| Fairfield | 2 | 3 | 1 |
| West of Hudson | 7 | 6 | 43 |
| Bergen | 3 | 2 | 14 |
| Passaic | 1 | 0 | 8 |
| Morris | 0 | 0 | 6 |
| Hudson | 0 | 1 | 3 |
| Essex | 1 | 1 | 2 |
| Union | 1 | 1 | 3 |
| Somerset | 0 | 0 | 2 |
| Middlesex | 0 | 1 | 3 |
| Monmouth | 1 | 0 | 1 |
| Orange | 0 | 0 | 0 |
| Rockland | 0 | 0 | 0 |
| Richmond | 0 | 0 | 1 |
| Outside Metropolitan Area | 5 | 6 | 7 |
| | 100% | 100% | 100% |

Source: (328)

In the same survey, the trip purposes of the passengers at all three airports were also obtained, and the results are summarized in Table II-14.

### TABLE II-14

Trip Purposes of Airline Passengers in New York
(From a 1956 Survey)

| Purpose of Trip | All Regions |
|---|---|
| All Personal Purposes: | 43% |
| Visit friends or relatives | 24% |
| Personal emergency | 3% |
| Sightseeing, visit resort | 10% |
| To or from school | 2% |
| Accompany husband on business trip | 2% |
| Establish new residence | 0% |
| Other personal purposes | 2% |
| All Business Purposes: | 57% |
| Visit customer | 12% |
| Visit branch or agent | 8% |
| Visit home office | 5% |
| Visit supplier | 4% |
| Attend business convention | 7% |
| Other business purposes | 10% |
| Combined business and personal | 11% |
| All Purposes | 100% |
| Number of Passengers (thousands) | 3,858 |

Future Plans for Airport Transportation

A long series of recommended additions and changes in the highway system have been made, and new concepts and plans for improvements in rapid transit have been advanced by the Metropolitan Rapid Transit Commission (266). If made, all such improvements are likely to alleviate the general transportation problem in the New York Area. However, no specific measures to improve airport transportation appear to be included.

New York Airways, Inc. (scheduled helicopters) does have plans for improving the service it provides airport travelers. Their fleet of single-piston engine, 13-seat helicopters are being replaced with multi-turbine, tandem rotor, 25-seat helicopters which cruise at 135 knots. Block speeds will be nearly doubled with the new aircraft--106 miles per hour as contrasted with 57 miles per hour of present helicopters. New York Airways projects that with the introduction of five of the new craft, their subsidy requirements per available seat mile will descend from 48¢ to 12¢. The new helicopters will offer considerably improved passenger comfort, reduced noise and vibration. Tentative plans call for peak hour, high-frequency schedules over routes connecting various heliports in the city center with special landing sites on the outskirts of the heavily populated metropolitan district. It is suggested that these peripheral landing sites be in large automobile parking lots, which provide ready access to private cars, buses, and even railroads. It would also be desirable if these sites were used as transit stops on routes to outlying communities and neighboring cities (114).

New York Airways believes that conventional rotary-wing aircraft are interim solutions to the kind of service they wish to provide, and they are looking forward to the introduction, in 1965, of V/STOL airliners which will provide higher speeds as well as the capability of vertical flight (114).

## Chapter 4. Airport Transportation in the Washington, D. C. Area

### The Washington, D. C. Area

The National Capital Region is defined as consisting of the following (273):

- District of Columbia
- City of Alexandria, Virginia
- City of Falls Church, Virginia
- Montgomery County, Maryland
- Prince Georges County, Maryland
- Arlington County, Virginia
- Fairfax County, Virginia
- Loudoun County, Virginia
- Prince William County, Virginia

The National Capital Region encompasses approximately 200 square miles and at present has a population of about 2,000,000. The population is expected to increase to 3,000,000 by 1980. In Table II-15 population figures comparing the years 1955, 1965, and 1980 are given. Total employment is predicted to rise by some 44% between 1955 and 1980 which would mean an increase of some 353,000 jobs. However, only 22% of this increase will actually be in the District of Columbia and only 12% or 39,000 additional jobs will actually be located in the downtown area. The Maryland counties are estimated to have 45% of the total projected increase in employment, and the Virginia counties 33%. The National Planning Commission believes that the existing pattern of land use and presently existing zoning will be the key determinants in shaping the future regional pattern such that the region in 1980 will resemble

today's general pattern, with the downtown Washington area remaining the focus of the region (273).

TABLE II-15

Population of the National Capital Region

| | 1955 | 1965 | 1980 |
|---|---|---|---|
| | 1,858,000 | 2,400,000 | 3,000,000 |
| District of Columbia | 852,000 | 900,000 | 950,000 |
| Montgomery County | 255,000 | 390,000 | 560,000 |
| Prince Georges County | 290,000 | 445,000 | 595,000 |
| Alexandria | 83,000 | 112,000 | 122,000 |
| Arlington County | 153,000 | 200,000 | 205,000 |
| Fairfax County & Falls Church | 165,000 | 282,000 | 467,000 |
| Loudoun County | 23,000 | 26,000 | 36,000 |
| Prince William County | 37,000 | 45,000 | 65,000 |

Transportation was one of the key forces which shaped the form of the development of the Washington, D. C. area. The advent of the electric streetcar brought with it the "finger-type" urban development which was followed by the influence of the automobile-dominated period in which the areas between the fingers were filled out. Up until World War II, people continued to live within 1/2 an hour of the downtown area where employment was concentrated. World War II brought with it a rapid increase and decentralization in employment centers. To this were added the modern regional shopping centers with their ability to compete with downtown retail houses and large new areas became ready for development. The distance from downtown areas lost much of its importance in determining the shape of area growth. This new growth tended rather to follow water and sewer lines and other public facilities as it freed itself

from dependence on the various transportation arteries. This new and rapid development, however, generated problems of its own. Key among these is today's overloaded and congested highway systems (273).

In 1955, there were 3,000,000 person-trips and approximately 2,000,000 vehicle-trips made during an average working day. (See Tables II-16 and II-17). Washington, D. C. experiences four peak traffic hours: from 7 to 9 a. m. and from 4 to 6 p. m. Nearly 40% of all automobile trips and almost 1/2 of all transit trips are taken during these peak hours.

TABLE II-16

Trips by Persons, 1955

| | | Thousands of Daily Trips |
|---|---|---|
| Total | | 3,070 |
| Type of Trip | | |
| Within study area: | | |
| Auto driver | 1,049 | |
| Auto, truck, taxi passenger | 847 | |
| Public transit passenger | 639 | |
| | | 2,535 |
| Into or out of study area: | | |
| Residents of study area | 131 | |
| Non-residents | 383 | |
| | | 514 |
| Through study area: | | 21 |

Source: (273)

TABLE II-17

Trips by Vehicles, 1955

| | Thousands of Daily Trips | Percentage of Total |
|---|---|---|
| Total...................... | 1,871 | 100% |
| Type of vehicle: | | |
| Private automobiles.. | 1,327 | 71% |
| Taxis............... | 267 | 14% |
| Trucks.............. | 277 | 15% |

Note: The origin and destination study did not gather information on trips of transit vehicles. Inclusion of such trips would increase the total by less than 2%.

Source: (273)

As the Nation's Capital, Washington presents certain unique characteristics especially important to the air travel market. Although ninth in population in the United States, Washington National Airport was third in number of commercial passengers passing through the airport in 1959. Not an important center of commerce or industry, the business of Washington is largely governmental (both civilian and military). Rapidly growing in recent years in the Washington area has been the research and development industry. As in Cambridge, Massachusetts, research companies, research foundations, and government research agencies have become elements of considerable importance in the commercial character of the area. Government, research, and the military are all important generators of air travel demand.

## Airports in the Washington Area

Washington National and Friendship International are the two commercial airports which presently serve the Washington area. A third, Dulles International, is scheduled to open in 1961.

Washington National Airport. Washington National Airport is situated on the Virginia side of the Potomac River about 3 miles south of downtown Washington, D. C. On a peak day during fiscal year 1959, Washington National Airport cleared 1,209 aircraft in a 24-hour period. In the same year, 4,700,000 passengers used the airport. Total aircraft movement for 1959--291,707--exceeded any previous year despite the business recession and strikes which shut down several air carriers and affected more than 50% of normal operations (444 ).

A modernization program is underway to meet future demands of air travel. With terminal facilities properly expanded, the airport should be expected to handle 6,000,000 passengers a year. This would be nearly 6 times that of the 1949 total (444 ). Already completed improvements include additional taxiways, high-speed turnoffs and an increase in aircraft parking areas. A new north terminal building with nine airline gates has been also built providing terminal facilities that include ticket counters, baggage rooms, parking space, taxi and limousine transportation, insurance sales and automobile rental service. With this addition of the north terminal the airport now has 30 airline gates. Automobile parking for passengers, visitors and employees has been increased. The traffic circle at the main terminal building, which formerly had only 27 parking spaces, has been modified to accommodate more than 100 cars. Parking time limits on metered spaces are normally 60 minutes. At present, there are total parking facilities for more than 3,500 cars.

Friendship International Airport. Friendship International is located about 35 miles northeast of downtown Washington. Transcontinental and international passengers flying jets which can not land at Washington National use Friendship. At present about 4,000 Washington area passengers per week use Friendship as compared with about 60,000 per week at Washington National. Almost all of these are jet passengers. The role of Friendship as an airport serving the Washington area will undoubtedly be considerably altered by the opening of Dulles International. At the present time, in terms of numbers of passengers involved, and in view of the forthcoming change in Friendship's role as the result of opening Dulles, Friendship does not represent a major problem in airport transportation and will not, therefore, be considered in detail here. It can be anticipated, however, that as the increase in air travel continues, the Washington area will utilize all three of the airports--each probably serving a somewhat different function and perhaps a different portion of the air traveler population. Transportation among all three airports will unquestionably be a matter of considerable importance for airport transportation in the not too distant future.

Dulles International Airport. To meet the projected increase in annual airline passenger traffic beyond 6,000,000 (the projected maximum at Washington National) and to accommodate long-range jet aircraft, Dulles International is being constructed about 27 miles west of downtown Washington on a 9,400-acre site. Being the first commercial airport designed specifically to handle the aircraft of the jet age, Dulles incorporates many new concepts in airport design. The mobile-lounge concept for transporting passengers between terminal and plane is one of these. The mobile-lounge, a bus-like vehicle on stilts, eliminates the need for conventional gates. The passenger enters the lounge from the terminal

lobby area and is carried by it to the plane. He moves from the ticket counter to his seat in the airplane all on the same level, without being exposed to weather conditions, and with only a short distance to walk. The mobile-lounge concept potentially is an important advance in one link of the airport transportation system.

A new high-speed highway is being developed to provide access to the airport. It will be approximately 17.8 miles long and will connect with the new circumferential highway that will encircle the city. Limousine and taxi service will be provided by operators presently serving Washington National. Hearings are presently being held to consider applications to provide helicopter service to Washington National, the city center, and possibly to Friendship.

## Airport Transportation in the Washington Area

Among the 27 large-hub airports in the United States, Washington National is the most favorably situated with respect to the downtown area, being only 3 miles distant. Airport transportation at Washington represents far less of a problem than it does at the 3 cities described previously. However, with the opening of Dulles and the continued proliferation of the Washington suburbs, the situation currently enjoyed by Washington with respect to airport transportation can be expected to come to resemble that of other cities more closely.

The local origins and destinations of passengers at Washington National Airport for an average day during the week of 5-11 December, 1960, are shown in Figures II-2 and II-3. Differences between the pattern for incoming and departing passengers are, for the most part,

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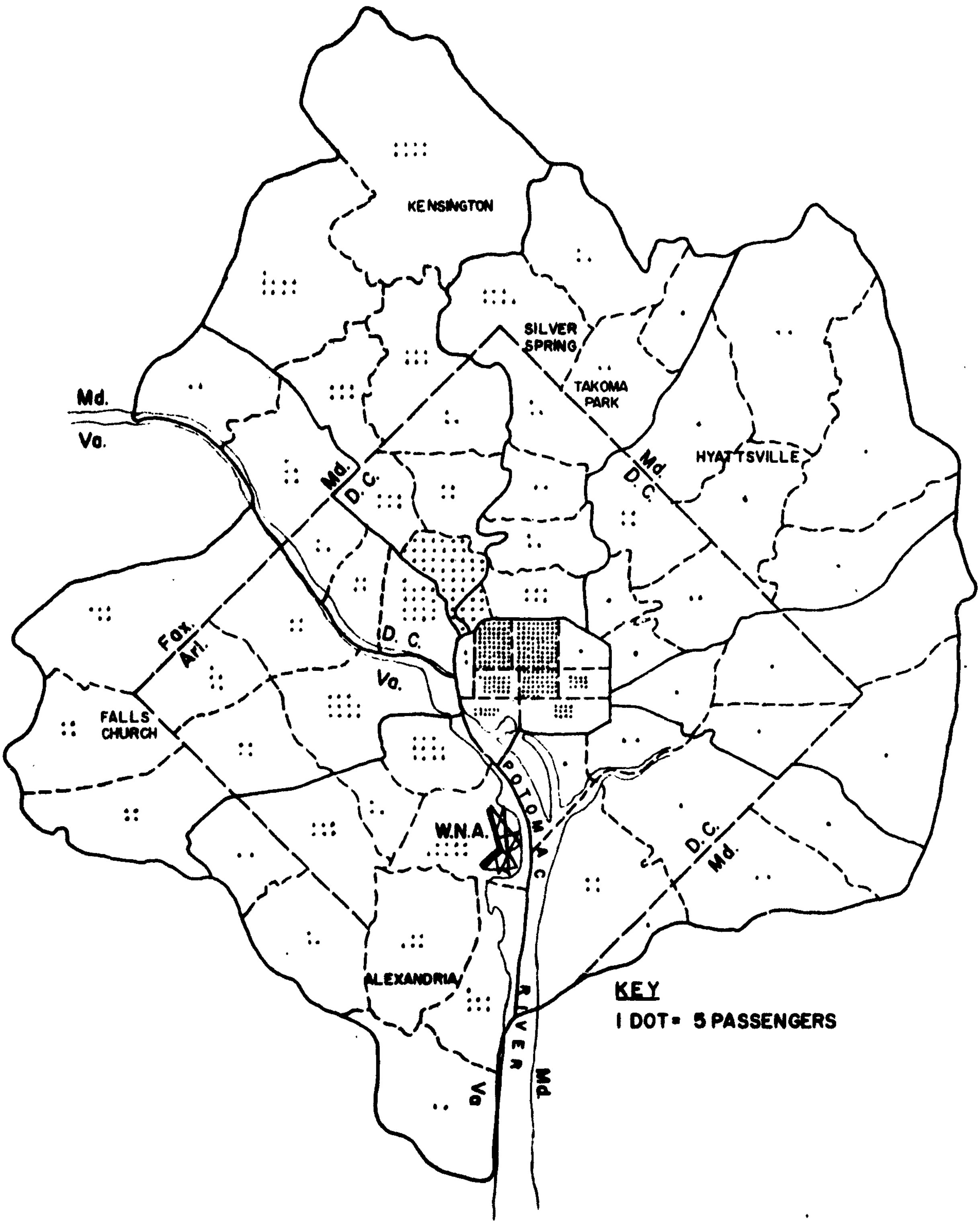
FIGURE II-2

# LOCAL ORIGINS OF EMPLANING PASSENGERS AT WNA

(FOR AN AVERAGE WEEKDAY DURING WEEK OF 5—11 DEC. 1960)

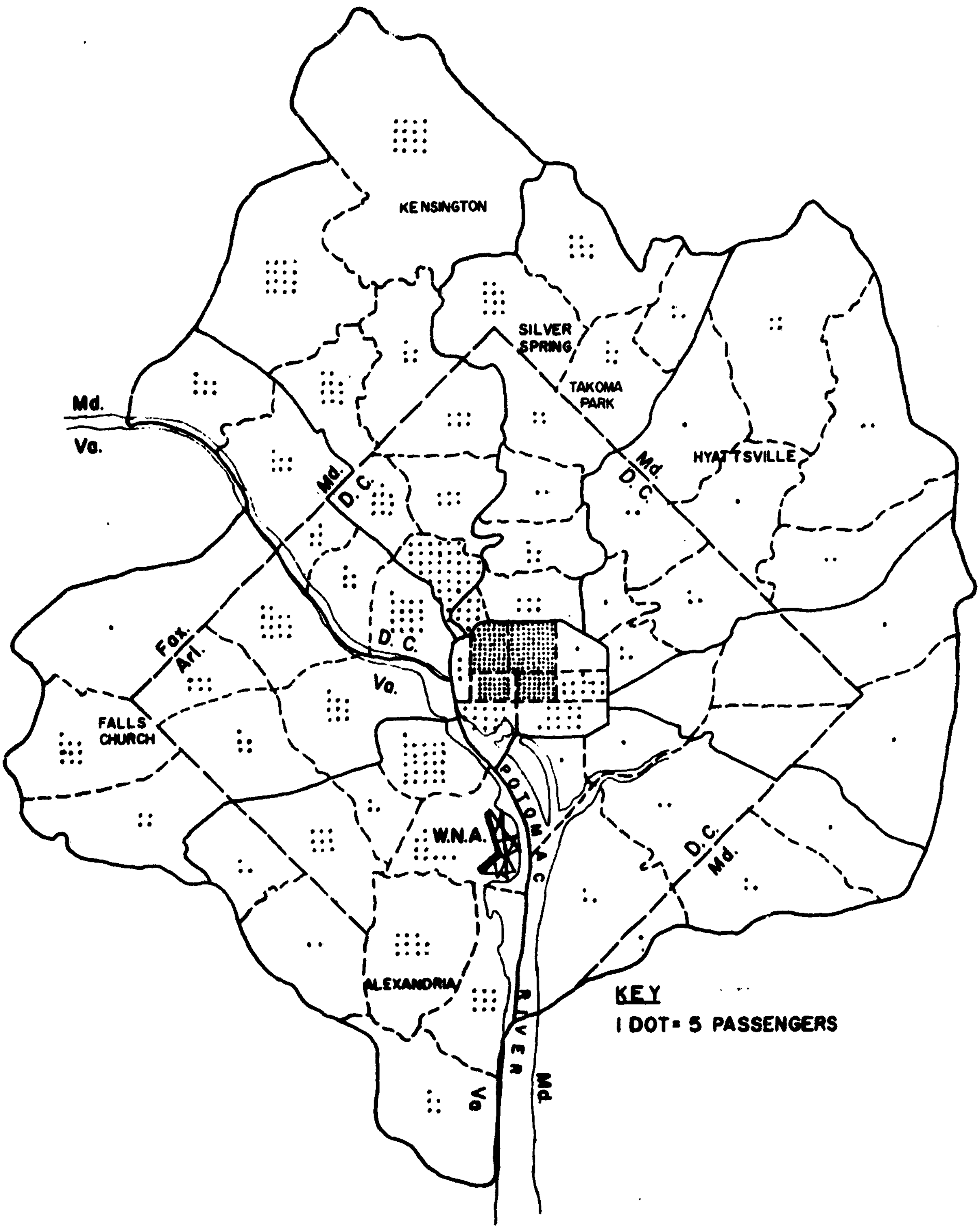



NOTE: FIGURES GIVEN ARE ESTIMATES BASED ON AN 11% SAMPLE FOR A ONE WEEK PERIOD. SEE APPENDIX B FOR DETAILS.

FIGURE II-3

# LOCAL DESTINATIONS OF DEPLANING PASSENGERS AT WNA

(FOR AN AVERAGE WEEKDAY DURING WEEK OF 5—11 DEC. 1960)




NOTE: FIGURES GIVEN ARE ESTIMATES BASED ON AN 11% SAMPLE FOR A ONE WEEK PERIOD. SEE APPENDIX B FOR DETAILS.

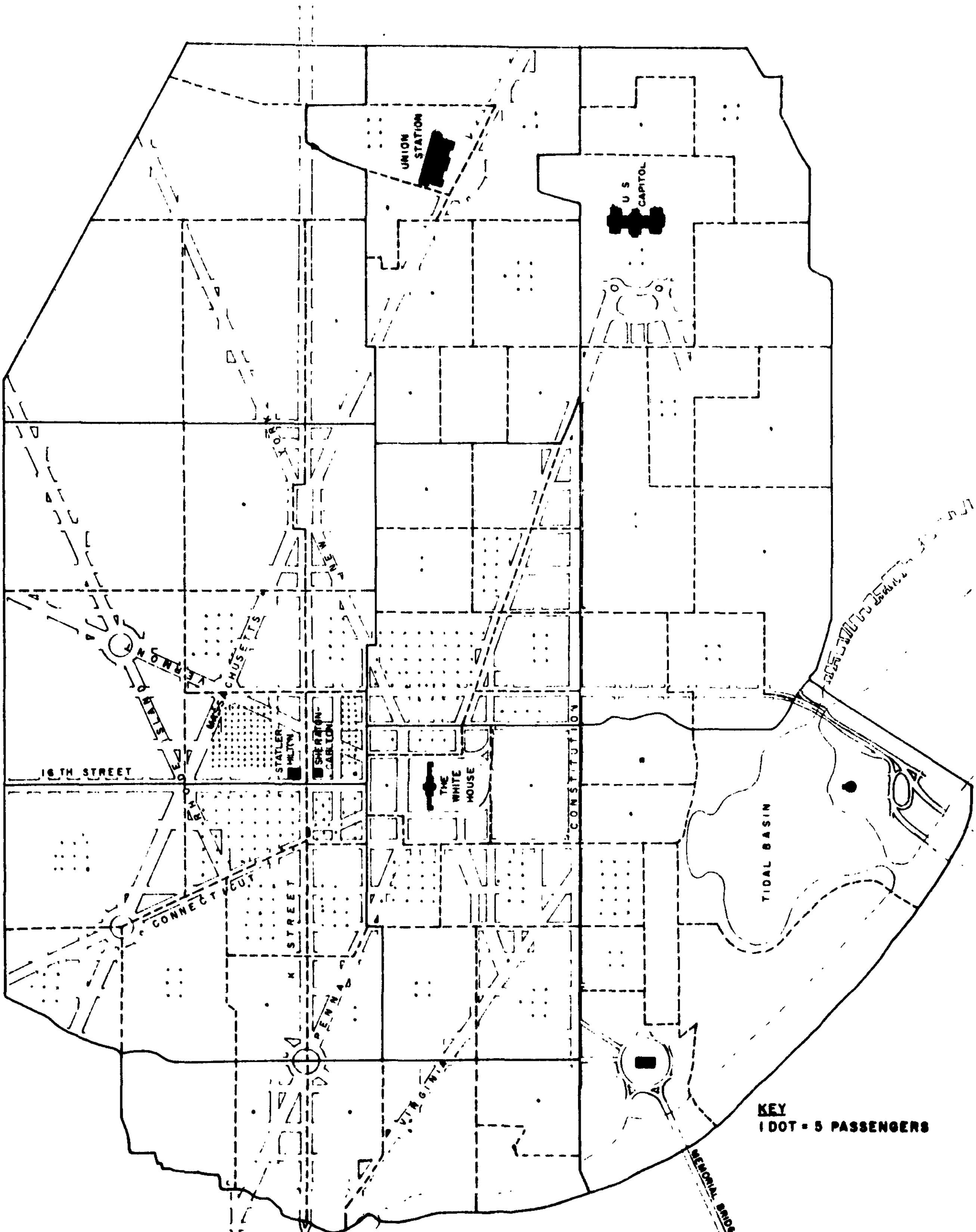
negligible. The largest single concentration, 37% of the total incoming and outgoing passengers, occurs in the sector encompassing downtown Washington. Except in that sector, only one other district has a concentration as high as 6% and all others range between 0 and 3%. Although in the area outside the central sector some patterning can be discerned, for the most part the origins and destinations are distributed thinly over the entire area. The districts within the central sector, as shown in Figures II-2 and II-3, are fairly large areas and only grossly define actual local origins and destinations. In Figures II-4 and II-5, the districts in the central sector have been further sub-divided into zones, thus permitting a more precise identification of origins and destinations. Ten of the 100 zones account for over 60% of the local origins and destinations in the central sector.

One question asked of outgoing passengers in the survey was: "Your complete trip to Washington airport took about _____ minutes?" The responses thus obtained are subject to some question in regard to accuracy of the estimates given. Even if inaccurate, however, they should at least reflect how long the passenger thinks it takes. Subjective time is often as important as objective time in influencing human behavior, and for that reason the data is here presented in Figure II-6. The mean time for all passengers is 26 minutes. Note should be taken of how this compares with mean ground travel time of passengers in the analysis presented in Part I, Table I-1. The average minimum ground travel time to and from 50 airports was estimated to be approximately 60 minutes, half of which (the one-way trip) is 30 minutes. The average trip times--minimum and maximum average--assumed for between downtown Washington and Washington National Airport for that analysis was 14 and 30 minutes. If we take the passenger's report of their trip

FIGURE II-4

## LOCAL ORIGINS IN THE DOWNTOWN AREA OF EMPLANING PASSENGERS AT WNA

(FOR AN AVERAGE WEEKDAY DURING THE WEEK OF 5-11 DEC 1960)

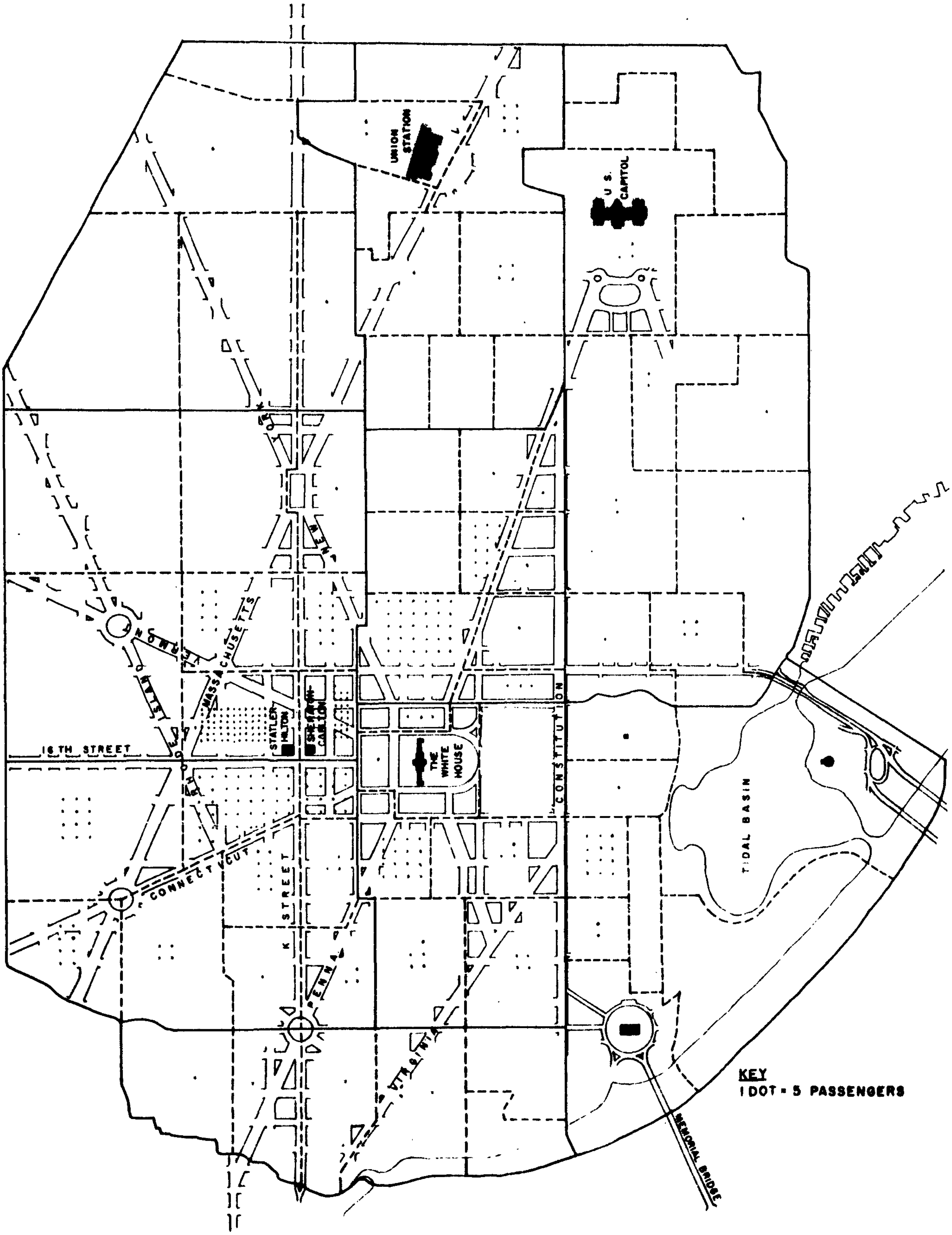



NOTE: FIGURES GIVEN ARE ESTIMATES BASED ON AN 11% SAMPLE TAKEN FOR A ONE WEEK PERIOD. SEE APPENDIX B FOR DETAILS.

FIGURE II-5

## LOCAL DESTINATIONS IN THE DOWNTOWN AREA OF DEPLANING PASSENGERS AT WNA

(FOR AN AVERAGE WEEKDAY DURING THE WEEK OF 5-11 DEC. 1960)

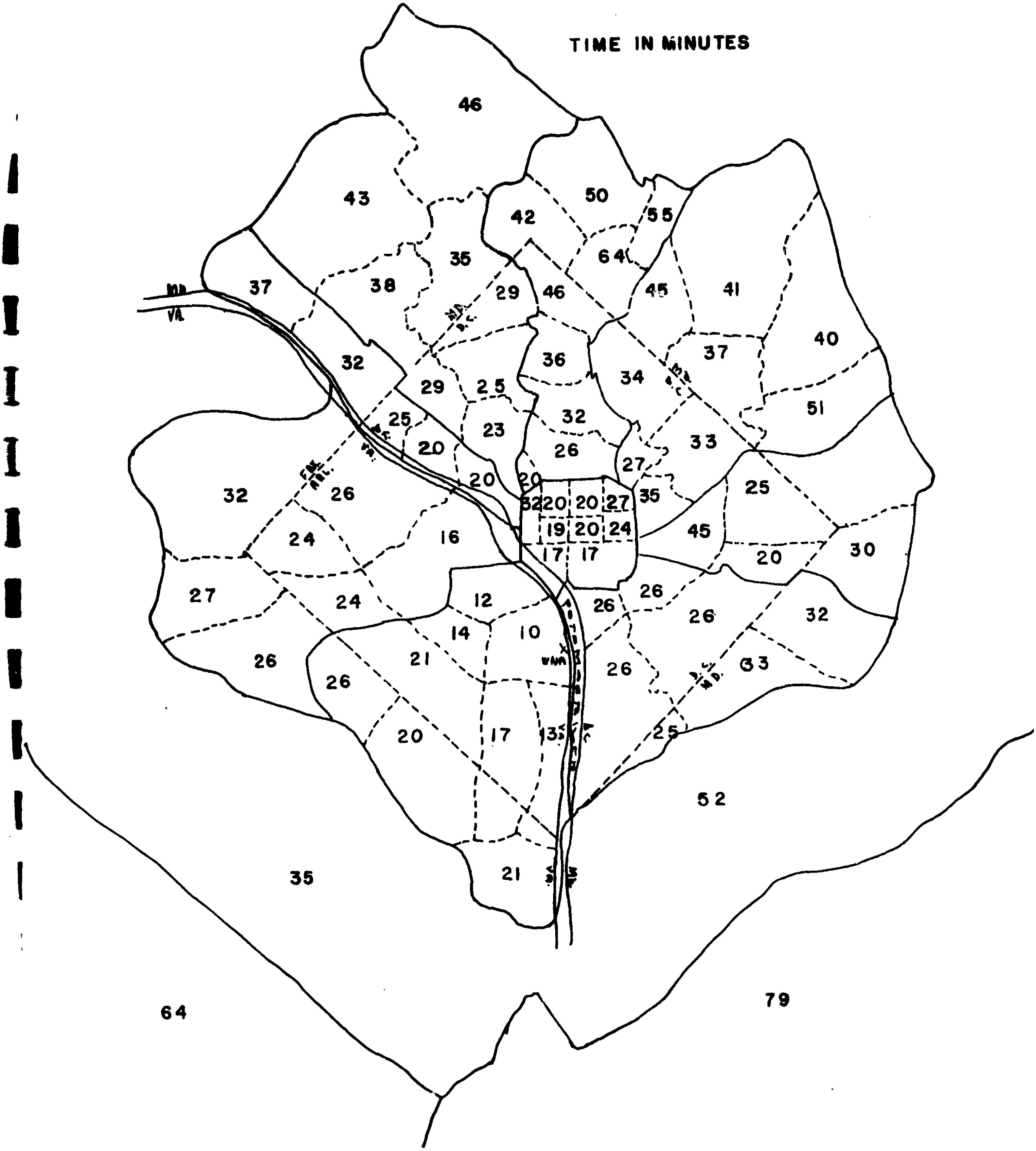



NOTE: FIGURES GIVEN ARE ESTIMATES BASED ON AN 11% SAMPLE TAKEN FOR A ONE WEEK PERIOD.
SEE APPENDIX B FOR DETAILS.

FIGURE II-6

# MEAN TRIP TIME BETWEEN EACH DISTRICT IN THE WASHINGTON AREA AND WNA

(OUTGOING PASSENGERS ESTIMATES-ALL MODES)



time as actual time, their mean time of 26 minutes tends to support the estimates used in the analysis in Part I.

Travel modes to Washington National Airport are given in Table II-18. Washington shows some notable differences in modes used as compared with the other cities studied. Only 30% of Washington National passengers (incoming plus outgoing) use private automobile to leave or arrive at the airport, whereas 44% use the taxi. Washington is the only one of the four cities in which the private automobile is not the most prevalent mode. This is true even though Washington is more an "automobile city" than it is a mass transit one.

TABLE II-18

Mode of Airport Transportation Used at Washington National Airport

| | PASSENGERS | | | | | |
|---|---|---|---|---|---|---|
| | TOTAL | | OUTGOING | | INCOMING | |
| MODE | Percent % | Number | Percent % | Number | Percent % | Number |
| Private auto | 30 | 1646 | 29.4 | 1054 | 30 | 592 |
| Taxi | 43.8 | 2206 | 48 | 1473 | 38 | 733 |
| Limousine | 16.1 | 814 | 11 | 339 | 24 | 475 |
| Bus | 1.2 | 65 | 1 | 39 | 1 | 26 |
| Rented car | 3.7 | 190 | 4 | 117 | 4 | 73 |
| Gov't vehicle | 1 | 51 | 1 | 42 | .5 | 12 |
| Other | 1.2 | 61 | 1 | 22 | 2 | 39 |
| | 100% | 5036 | 100% | 3086 | 100% | 1950 |

Note: Data from an 11% sample of passengers at Washington National Airport for one week in December, 1960.

In our 1960 Washington survey, passengers were asked to describe the type of their local origin or destination; i. e., residence, business, governmental, etc. Table II-19 summarizes types of origins and destinations by sector. Except for the central sector in which hotel origins and destinations are predominant, in all other sectors the private residence is by far the most frequent type of origin or destination. Private residences account for 38% of the total origins and destinations and 80% of those which lie outside the central sector. Hotels and motels account for 33% of the total and 71% of the hotel-motel origins and destinations were in the central sector. Less than 30% of all local origins and destinations are other than permanent or transient residence.

The modes of airport transportation available in the Washington area are the private automobile, limousine, taxi, and the transit bus.

Private Automobile. Thirty-three percent of the passengers arriving at or departing from Washington National Airport use a private automobile in their trip. This compares with the 41% in the New York area, 78% in San Francisco, and 34-46% in Chicago.[1] The average person using an automobile to come to the airport took 29 minutes driving time. About 30% of those who traveled to the airport in their own car left it parked there for the duration of the trip.

The street system, originally planned by L'Enfant in 1791 and later extended along the same lines, carries the bulk of the automobile

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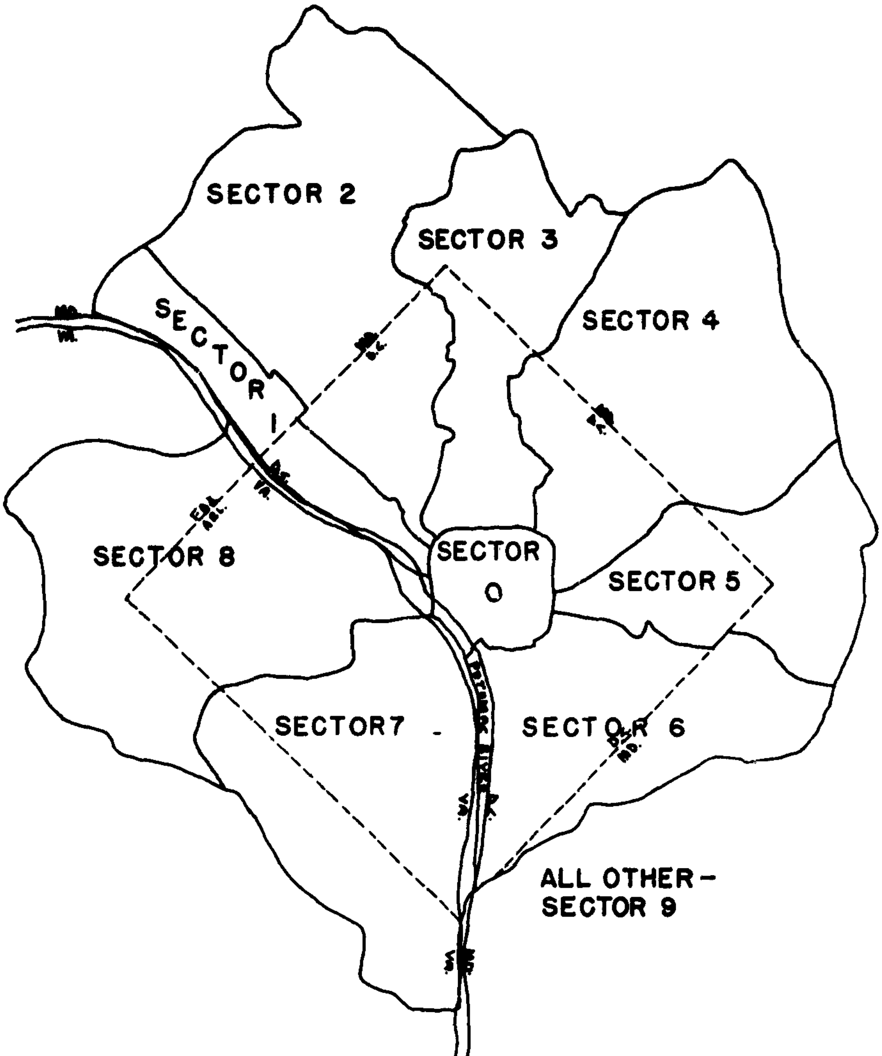
[1] New York data from survey in 1956, enplaning and deplaning passengers;

San Francisco data from survey in 1958, enplaning passengers only;

Chicago data from survey in 1957, enplaning and deplaning passengers.

TABLE II - 19

# TYPE OF ADDRESS OF LOCAL ORIGINS AND DESTINATIONS




PERCENT OF PASSENGERS GOING TO OR COMING FROM ADDRESSES OF EACH TYPE

| TYPE OF ADDRESS | SECTOR 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PRIVATE RESIDENCE (OWN) | 1.3 | 3.4 | 6.5 | 2.9 | 0.8 | 0.1 | 0.7 | 3.2 | 3.6 | 7.6 | 30 |
| PRIVATE RESIDENCE (OTHER) | 0.7 | 0.8 | 1.0 | 1.2 | 0.2 | * | 0.2 | 1.0 | 1.1 | 1.4 | 8 |
| HOTEL, MOTEL | 24.0 | 0.2 | 4.6 | 0.7 | 0.2 | 0.0 | * | 1.8 | 0.6 | 1.0 | 33 |
| INDUSTRIAL | 0.1 | * | 0.2 | 0.1 | 0.2 | * | 0.0 | 0.2 | 0.1 | 0.8 | 2 |
| BUSINESS | 6.9 | 0.4 | 0.3 | 0.4 | 0.2 | * | 0.1 | 0.3 | 0.2 | 0.6 | 9 |
| GOVERNMENTAL | 6.8 | * | 0.6 | 0.3 | * | * | 0.7 | 2.5 | * | 1.9 | 14 |
| OTHER | 2.2 | 0.4 | 0.1 | 0.3 | 0.4 | 0.0 | 0.1 | 0.2 | * | 0.5 | 4 |
| | | | | | | | | | | | 100% |

NOTES: * EQUALS LESS THAN 0.1%
SEE APPENDIX B FOR MORE DETAILED ANALYSIS

and transit traffic within Washington. A few freeways and parkways have been built. Of these, approximately 15 miles are located within the District of Columbia and about 32 miles are in Virginia and 34 are in Maryland. There is no real "open system" of free-flowing, high capacity traffic arteries (273, p. 30). Much of the freeway mileage is in the outer part of the region with very little being in the center where it is most needed. Plans for a modern system of freeways have been prepared and major segments are--or soon will be--under construction. Upon completion of the new highway improvements, some shifts in travel habits are to be expected. Transit service should be at least temporarily improved on the local streets. The automobile users, however, will reap the primary benefits of this new highway system.

Taxi. About 43% of the passengers at Washington National Airport use the taxi to get to or from the airport. This compares with 28% in the New York area, 6% in San Francisco, and 33-35% in Chicago.[1] The average taxi trip to the airport took 19 minutes.[2]

In Washington, taxi drivers either own their own taxi or rent it on a per diem basis. They charge on the basis of a zone system rather than a meter. The basis of the zone charging system is established by the Public Utility Commission and is too complex to be described here.

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[1] New York data from survey in 1956, enplaning and deplaning passengers;

San Francisco data from survey in 1958, enplaning passengers only;

Chicago data from survey in 1957, enplaning and deplaning passengers.

[2] Passenger's estimates.

From downtown Washington, taxi trip time to Washington National Airport is about 20 minutes; the fare is $1.50. Airport Transport, Inc. operates a special fleet of cabs which service the airport only. These cabs are licensed to pick up customers either at the airport or at any point to which they have been called, but they are not allowed to cruise for passengers. Regular cabs can not wait at the airport for customers, but they can drop off or pick up customers if it does not involve waiting.

Public Bus. About 1% of the passengers use the one bus line which serves Washington National. It operates between Alexandria and downtown Washington on a 10-minute schedule during the day. (Washington National is situated about midway between Alexandria and downtown Washington.) Buses run non-stop from 12th and Pennsylvania Avenue, N. W. to the airport in 12 minutes during off-peak hours and approximately 20 to 25 minutes during rush hours. Fare is 20¢.

Limousine. Approximately 16% of the passengers travel to or from the airport by limousine. This compares with 28% in New York, 16% in San Francisco, and 16-27% in Chicago.[1]

Limousine services at Washington National are operated by Airport Transport, Inc., which also operates a fleet of airport cabs. In total, the company has a fleet of over 130 vehicles serving airport users exclusively. Approximately 1,500 trips are made and about 4,000 passengers

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[1] New York data from survey in 1956, enplaning and deplaning passengers;

San Francisco data from survey in 1958, enplaning passengers only;

Chicago data from survey in 1957, enplaning and deplaning passengers.

carried daily, running well over 7,500,000 miles annually. The unique feature of the D. C. limousine service which distinguishes it from most companies of this type is that it is an unscheduled operation which means that waiting time has been cut practically to zero at the airport. The limousine will deliver passengers to any point in the area and pick them up anywhere in the District of Columbia and Virginia, but not in Maryland; thus, they do not rely on a limited number of limousine pick-up and drop-off points. Limousine charges work out to approximately 40¢/mile.

Air Media. There exists no helicopter connection at present between Washington National Airport and the District of Columbia. There is a scheduled fixed-wing air connection between Washington National and Friendship Airport, operated by Potomac Airlines. Planes depart every hour on the hour; the fare is $8.50.

## Future Plans for Airport Transportation in the Washington Area

While not specifically intended to improve airport transportation, the transportation plan recommended by the National Capital Planning Commission in 1959 would provide improvements in transportation in the entire area and would thereby benefit the airport traveler (273, p. 1). Recommended are:

(1) A network of freeways which permits quick travel for the public between two parts of the region, even during rush hours.

(2) A new kind of fast and comfortable public transit service between the downtown area and the suburbs. This new transit service should consist of modern express buses on eight of the routes that lead downtown. These buses would travel on freeways at high speeds and make few stops until they reach the downtown street system. Another component of this new

system would be a modern rail transit on the four heavily traveled routes. These rail lines are envisioned as located in subways in the inner areas of the District of Columbia and in the median strips of freeways, or own their own right-of-way elsewhere.

(3) Arterial streets and highways extensively improved to carry automotive traffic not served by the freeways.

(4) Expanded and improved local transit service on arterial and local streets in order to carry those passengers who are not served by the new bus and railroads.

It is contended that the recommended system will meet the needs of the region when the population has reached the 3,000,000 mark, which should occur around 1980.

A high-speed, limited access highway is being constructed to serve Dulles International Airport. Consideration is now being given to instituting helicopter service at Dulles which would serve Washington and the other airports in the area.

## Chapter 5. Summary of Case Studies

The case studies served a valuable function in providing specific data and background information for the analysis reported in Part III. The four cities display quite different situations and present somewhat different problems for airport transportation. In so doing, they have been helpful in illuminating many of the problem areas of airport transportation.

Two of the major obstacles to incisive case studies of airport transportation are:

(1) The paucity of available data.

(2) The non-comparability of data where it does exist.

The first means merely that the problem has received very little attention. Only a few studies concerned themselves primarily with airport transportation. Most data was found in studies directed at other problems. The second is an indication of the sporadic nature and the limited scope of the studies that have been made. As the reader has seen, only very tenuous comparisons can be made between data collected in different cities. The studies have been conducted in different years, for different purposes, and in different ways. Assumptions and definitions are apt to vary from study to study; methods of data collection and the population sampled are frequently quite different. Almost no trend data is available indicating that the studies, for the most part, are one-time events.

The above commentary is not intended as adversely critical of the studies from which the data presented in Part II have been drawn. To the contrary, these studies were often of a high caliber and more than adequately fulfilled their purposes. They can hardly be criticized for failing

to achieve goals they never had and the simple fact is that almost no research has had as its objective the study of airport transportation problems.

At least one common finding should be noted. Where data were available, it consistently showed that about 1/3 of the passenger's local origins and destinations were concentrated in the downtown hotel districts and the remaining 2/3 were widely distributed with few, if any, concentrations. A number of the implications of this fact have been discussed in Part I.

Except for Washington, D. C., the private automobile was the most frequently used mode of airport transport. This transit accounted for an almost negligible percentage of passengers, while taxis and limousines together approximately equaled the private automobile in popularity. The helicopter, while presently accounting for a small proportion of airport transportation, is showing rapid growth in both Chicago and New York. Of all the modes in current use, the helicopter offers the greatest potential for significant improvements in the service offered. This consideration is primarily true because all other modes are far more dependent on the existing street and highway system than is the helicopter. Inherently, therefore, the helicopter possesses a degree of flexibility denied to systems which operate in the general transportation milieu. Whereas it appears that the potential of mass transit systems have not been exploited for airport transportation, it also appears that air travelers do not wish to ride mass transit to and from the airport.

The primary conclusions drawn from the case studies (and other material as well) have been incorporated into the statement of the problem in Part I and, therefore, will not be repeated.

## PART III. ANALYSIS

### Approach

The purpose of this Part is to identify and isolate the factors which influence airport transportation in order to specify parameters which can be used to evaluate present and proposed systems.

Basic Concepts. To say that we are dealing with a complex and highly interactive problem is perhaps trivial, but nonetheless true. To believe that it is possible to sort out and quantitatively specify all of the complex interrelationships is wishful thinking in view of the stage of development of the present state-of-the-art. The more realistic aim of this study is to identify a set of major parameters generic to any system and devise means of using these parameters to comparatively evaluate different systems. While it is recognized that not all relevant parameters can be identified within the scope and means of this study, it is believed that sufficient advances toward that goal can be made to justify the effort.

By parameter, we mean a property of a system, its performance, or its environment which can assume different values and whose value directly or indirectly affects the attainment of the systems's objective.[1] System parameter is the fundamental concept in the present approach. Any parameter has two conceptual aspects which form the next two basic concepts, system requirement and system performance.

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[1] The term parameter has at least six distinctly different definitions in common usage. The above usage is taken from: McGrath, J. E., & Nordlie, P. G. Synthesis and comparison of system research methods. Arlington, Virginia: Human Sciences Research, Inc., 1960. (ASTIA Document No. 234 463.)

A system requirement is a specific value on a parameter which must be characteristic of the system or which the system must achieve in order for it to fulfill its objective or mission. System performance is a value on a parameter which the system actually does achieve. Thus, conceptually, evaluation is a determination of the discrepancy between the requirement on a parameter and the system's performance on the same parameter. The requirement is the criteria against which performance is assessed.

Depending upon the evaluation question that is asked and the nature of the system under consideration, the form of the evaluation process will differ. For instance, the question may concern simply the total effectiveness of a system. In such cases, it is possible to evaluate on the basis of a single parameter; *e. g.*, the hit-probability of an anti-missile-missile system, to take a simple example from another field. The evaluation in this case is the statement of the discrepancy between the required hit-probability and the hit-probability actually achieved by the system--it is a single criterion evaluation. Any number of systems can be directly compared, and their relative effectiveness (on this parameter) immediately specified. The question of which is "better" is given directly by the comparison. Notice, however, that no information is given about any other parameter which may have bearing on the question, "Which system should be built?" It could be, for example, that system A enjoys a 2% superiority over system B in performance achieved, but both A and B exceed the requirements. If only one parameter is used in evaluation, other information which may have equally critical bearing on the original question is ignored. It may be, to use one of many possible examples, that system A may cost four times as much as system B and this fact is not reflected in the evaluation.

However, whenever more than one parameter is considered, the choosing of which is the "better" system poses a fundamental problem in evaluation whenever one system is not consistently superior to the other on all parameters (and this is the most typical case). Unless the several parameters used can be specified in a common set of terms (i. e., the mathematical relationships among the different criterion values can be specified), the evaluation process can not give directly the answer to the question "which is better?" For example, how many units of cost is equal to one unit of hit-probability? If each parameter can not be expressed in the units of each other, then the relative significance, or the proportional weight, of each parameter is unknown. In such a circumstance, in terms of the previous example, if the hit-probability of system A is greater than B and the cost of A is greater than B, the direct comparison of the two systems on hit-probability and cost does not specify which system is "better" because it depends upon the unknown relationship between cost and hit-probability.

This brief review of a fundamental problem in assessment has been introduced as background for the choice of the path we have chosen to follow in our approach to the evaluation of airport transportation systems. There have been three different typical responses to this fundamental problem:

(1) Ignore it and make evaluations on intuitive bases.

(2) Select what is believed to be the most important single criterion; evaluate on the basis of it alone; and ignore all other factors.

(3) Specify as many relevant criteria as is possible; measure discrepancies between systems on each criterion; establish an "evaluation profile" for each system; and make an essentially intuitive or consensual judgment on the basis of the comparison of profiles.

The third alternative is the form of evaluation at which this study is aiming. It is chosen for essentially three reasons:

(1) Which airport transportation system or combination of systems is "better" or most desirable is, in the end, a human value judgment of the weights that should be assigned to various parameters. The profile approach offers the potential of supplying all of the relevant objective information on which the ultimate value judgment can be made. It is superior to alternatives (1) and (2) in that it objectively defines the choices to be made (as (1) does not), and it does not necessarily ignore pertinent information (which (2) does).

(2) The profile approach has the inherent advantage of being a diagnostic tool. Its use can serve to identify specific weaknesses in otherwise desirable systems. Thus, the profile can provide information as to what aspects of a system effort can be wisely expended to improve.

(3) At present, it is necessary to treat separately some parameters which there is reason to believe can, in principle, be related to each other. The profile approach facilitates identifying where these possibilities exist. It offers the advantage, therefore, of being a nucleus for a more sophisticated and highly developed evaluation process. Alternatives (1) and (2) do not offer this growth potential.

The varied and diverse material to be presented in the following pages can be understood as a coherent whole only when viewed from the standpoint of the purpose and approach of this part of the research effort. Figures III-1 and III-2 may be helpful visual devices to express conceptually the approach being taken and the ultimate form of evaluation toward

which this research study is aimed. Figure III-1 is intended to express the basic elements in the approach. The first step is to identify meaningful objective and generic parameters on which systems can be appropriately compared. The second step is to specify specific values on the parameters which a system must attain for it to achieve its objective. This step usually is not possible for the general case but must be done in each specific case (for example, the number of passengers a system must be able to handle can not be specified in general, but must be specified for the particular location and time period under consideration). The third step is to obtain actual performance measures or, in the case of systems not yet in being, estimate of actual performance. (Performance in this sense is an inclusive term which encompasses properties of the system as well as outputs.)

FIGURE III-1
CONCEPTUAL APPROACH TO THE PROBLEM

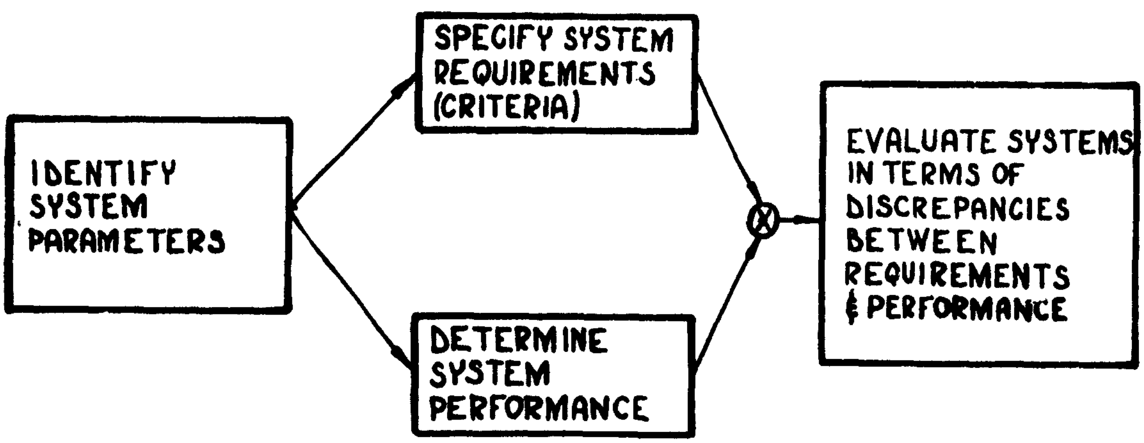
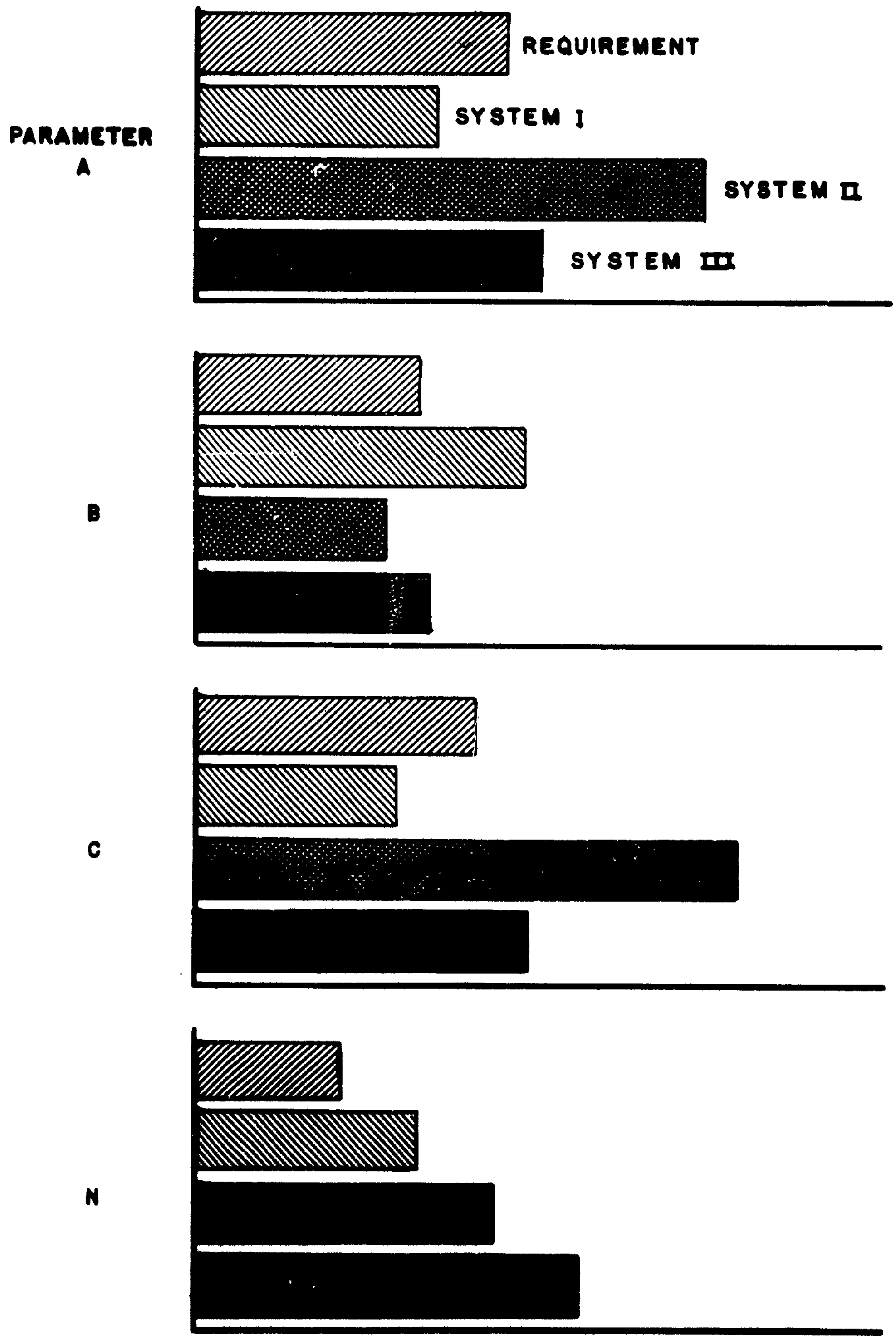


FIGURE III - 2

AN IDEALIZED FORM OF THE EVALUATION END-PRODUCT



Finally, for each parameter identified, the discrepancy between the performance and the requirement is determined. The determination of a set of such discrepancies for each of two or more systems intended to perform the same job in the same locality is the end-product of the evaluation process toward which this approach leads. Figure III-2 depicts an idealized conception of this end-product.

In the remainder of Part III, the reader may find himself lost, at times, in details and procedures--the relevance of which may not be obvious. He should bear in mind that the aim of all of the effort in Part III is to discover meaningful, objective, and generic parameters which can be employed to evaluate airport transportation systems. The process will differ as a function of the nature of the particular class of parameters under consideration; i. e., economic parameters must be dealt with somewhat differently than psychological parameters. Differences in the state of knowledge in different fields, and realistic considerations of practicality have meant that the conceptual overview just presented could not be strictly adhered to in each particular case. Nonetheless, the goal is the same in each case, although the means to it vary considerably. As is to be expected, greater progress has been made with regard to some factors than others.

A chapter is devoted to each of five major classes of factors: kinematic, economic, engineering, psychological, and regulatory. The way in which the factors identified in Part III can be applied to evaluation in a specific instance is described in Part IV.

# Chapter 1. Kinematic Factors

The term "kinematic" requires some explanation as it is not in common use in the way we have employed it. The basic function of any transportation system is to move some load to a particular location within some time period. There is need of a descriptive term which encompasses load, geographic distribution and time collectively so that these primary factors of a transportation system can be conveniently denoted. Because of the fundamental character of these factors to any transportation system, we found it desirable to have a word for them which is comparable and parallel to the more immediately obvious labels available for other classes of important factors such as economic, engineering, psychological, and regulatory.

Kinematics is a branch of physics which is concerned with the motions of particles or bodies considered apart from causative forces. The ingredients of kinematics are particles, geometry, and time. These being the same elements we wished to denote, the analogy from physics appeared suitable and the term kinematic factors, or kinematics, was, therefore, adopted.

## Kinematic Parameters

In any kind of transportation network we may consider, there are arrivals, through time, at each of the various stations, points or nodes of this network. Each of these arrivals has a desired destination which is some other station in the network. This is a very general conception which can encompass a homogeneous kind of network (*e.g.*, streetcars, or airlines), or it can encompass complex kinds of networks in which, for

example, feeder-lines of busses or limousines bring people to central collection points whereupon they transfer to other high-speed express conveyances. Initially, for purposes of exposition, we shall explore only the homogeneous type of network, where vehicles with a stated capacity and speed capability, and either fixed schedules or some kind of departure discipline, take passengers from point to point of the transportation network.

The first important consideration in analyzing or evaluating a transportation system is its ability to transport the load which demands movement (the load, in this case, being number of passengers). With respect to kinematic factors, a system either can move a given load or it can not. If it can, its ability differs from any other system only in terms of how rapidly it moves the required load.

The time which it takes to move the load is dependent on three parameters which are generic to any system: vehicle capacity, headway between vehicles and travel time between the two points. Between any two points, if the load is given and values on these three parameters are specified, then the time required for the system to move the load is readily calculated.

Because of the inherent relationships among the kinematic factors, we are afforded the opportunity of not merely comparing the values of these factors between systems, but of comparing the result of the interaction of headway, capacity, and travel time as they determine the ability of the system to move the given load. It will be shown that their interaction in any specific case generates a distribution of number of passengers against total trip time. It is this distribution which will be used as a measure of the kinematic performance of a system.

## Description of Kinematic Requirements

Arrivals at each point in the network vary: (1) in time of arrival at the point and, (2) in terms of to which other point in the network they wish to go. If there are n points in the network where passengers may enter or leave, then there are $n^2$-n possible distributions of number of passengers arriving over time. These assumed to be stochastic functions of time with some discernible patterns which may be studied and measured in order that we may work with them. This is not a very strong or unreasonable assumption.

If we can determine and predict these microcosmic distributions, then we can also determine their macrocosmic implications for a transportation network as a whole, or examine any kind of subdivision of the whole with which we are concerned. Such an analysis rests on our ability to take any two points in the network, A and B, and specify the statistical characteristics of the traffic that is generated at A with a desire to go to B.

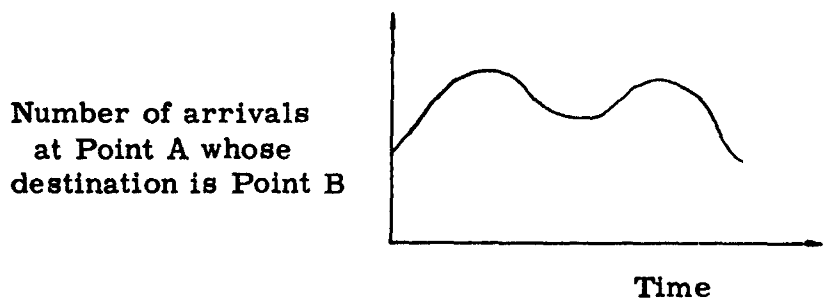
If the transportation system for a given network happens to be a system in-being rather than a proposed or projected system, the statistical parameters of the kinematic distribution can be determined in great detail and great precision. The hourly, daily, and weekly fluctuation of the mean could be established as well as the nature and fluctuation of the variation around the mean. However, in situations where we wish to make projection into the future, the further ahead we project, the more inaccuracy is introduced. In such cases considerations of fluctuations about the mean, seasonal fluctuations, day of the week fluctuations, etc., might be successively dropped. Perhaps only peaks and troughs and their effects

on peak scheduling and slack-period scheduling respectively would be examined. It depends on judgments made about the degree of accuracy obtainable and desired in the projections, and on the consequent degree to which more detailed processing of the information is justified.

The $n^2$-n distributions, referred to above, can be considered as transportation demand functions for each ordered pair of points in the network. Each distribution can be described completely in terms of arrivals, space, and time. Space is given by the particular two points involved. For each ordered pair of points, e.g., AB, there exists a distribution of arrivals through time (number of people arriving at A in any time interval who desire to go to B). Figure III-3 is an example of such a distribution, for the pair of points AB, which distribution specifies one requirement the transportation system must fulfill.

FIGURE III-3

Hypothetical Kinematic Requirement




The total set of $n^2$-n of these functions (one for each ordered pair of points) is the total kinematic requirement which the transportation system must handle.

## Kinematic Measures of Transportation System Performance

For our example of two points, Figure III-3 specified a hypothetical kinematic requirement of moving a load, the size of which varies through time, from A to B. From a kinematic standpoint, the only measure of how well a system performs this requirement is the time it takes to do it. A measure of this time is a measure of performance. We take as a basic assumption that the less time a system takes to move the load, the better the system from a kinematic standpoint.

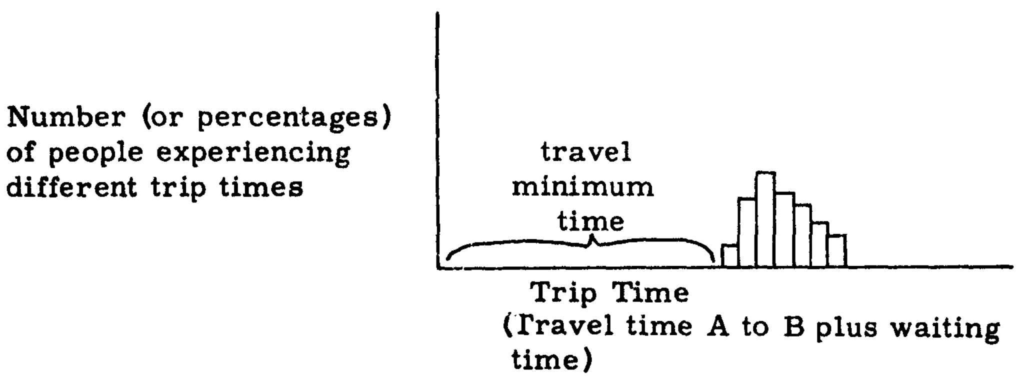
If we consider two systems, each faced with the same requirement function to handle (Figure III-3), and the first system transported every individual in less time than the second system transported him, then, within the context in which we are dealing, the first system is clearly superior to the second. However, this simple relationship may not hold, i. e., some of the people may be transported in less time by system #1, but at the same time other people may be transported in more time by system #1. This makes the problem of evaluating the two systems a good bit more subtle, and it imposes the need for a more sophisticated measure of system performance than simply faster or slower, since neither applies fully and both apply partly.

Recall at this point that the requirements function specifies the time at which a number of people are available at A who wish to go to B. If some or all of them do not begin their trip to B immediately upon their arrival at A, it becomes necessary to add the time they must wait to begin the trip to the actual time of traveling. Thus, from the time they are available at A to the time they arrive at B is a time interval that includes two components: waiting time and travel time. This total time interval, we will call trip time. The distribution of trip times which a given

system produces for a given requirement function is a measure of how the system performed the requirement. To illustrate, let us say that the time required for the vehicle to make the trip from A to B is T minutes. That means that if there are people who are fortunate enough to arrive at A at the same instant that a vehicle is ready to depart for B, and if that vehicle has a vacant seat or space which they may occupy, then these people will require T + 0 minutes for their entire trip. If they had to wait for 1 or 2 or 3 minutes, then their total time would be T + 1, T + 2, or T + 3, respectively. If there were no space available for them on the first vehicle departing for B from A, then, of course, they would have to wait for the next one, and this waiting time would have to be added to T also. We now call this function the kinematic performance function and depict it in Figure III-4.

FIGURE III-4

Hypothetical Kinematic Performance Function




The ordinates of this function are either absolute number of people, or percentages of total number of people. In either case, the function will have the same shape, and the context which is used will usually remove any ambiguity about whether numbers or percentages are intended.

It is an examination of this entire function that reveals how the people who wanted to go from A to B are transported through time. If we wished a picture of the kinematic performance function of an entire network, we would need the kinematic performance functions of all the $n^2$-n kinematic performance functions of the individual runs, with ordinates expressing absolute numbers. We could then simply add all these functions together (the sum of all the ordinate values corresponding to each abscissa taken one at a time starting with zero). The result of this operation would be a function similar in appearance to that of Figure III-4, but it would refer to the entire network rather than merely to one run.

Any of the possibilities intermediate between the single run and the entire network could be examined. For example, the total of all possibilities going away from a single point could be singled out for examination. Say X were this point. We would combine the functions as described above for the runs XA, XB, XC, etc., and their combinations would give us the combined function sought.

Kinematic Comparison of Two Transportation Systems

In the sense in which we have been considering transportation systems, each one of them has three generic parameters, specification of which serves to describe a given system completely. The three generic parameters are:

(1) Capacity of the vehicles.

(2) Travel time (speed of the vehicles is a more basic consideration, however, it means nothing in its impact on the performance function unless we consider its interactions with route congestion, intermediate stops and starts, etc.)

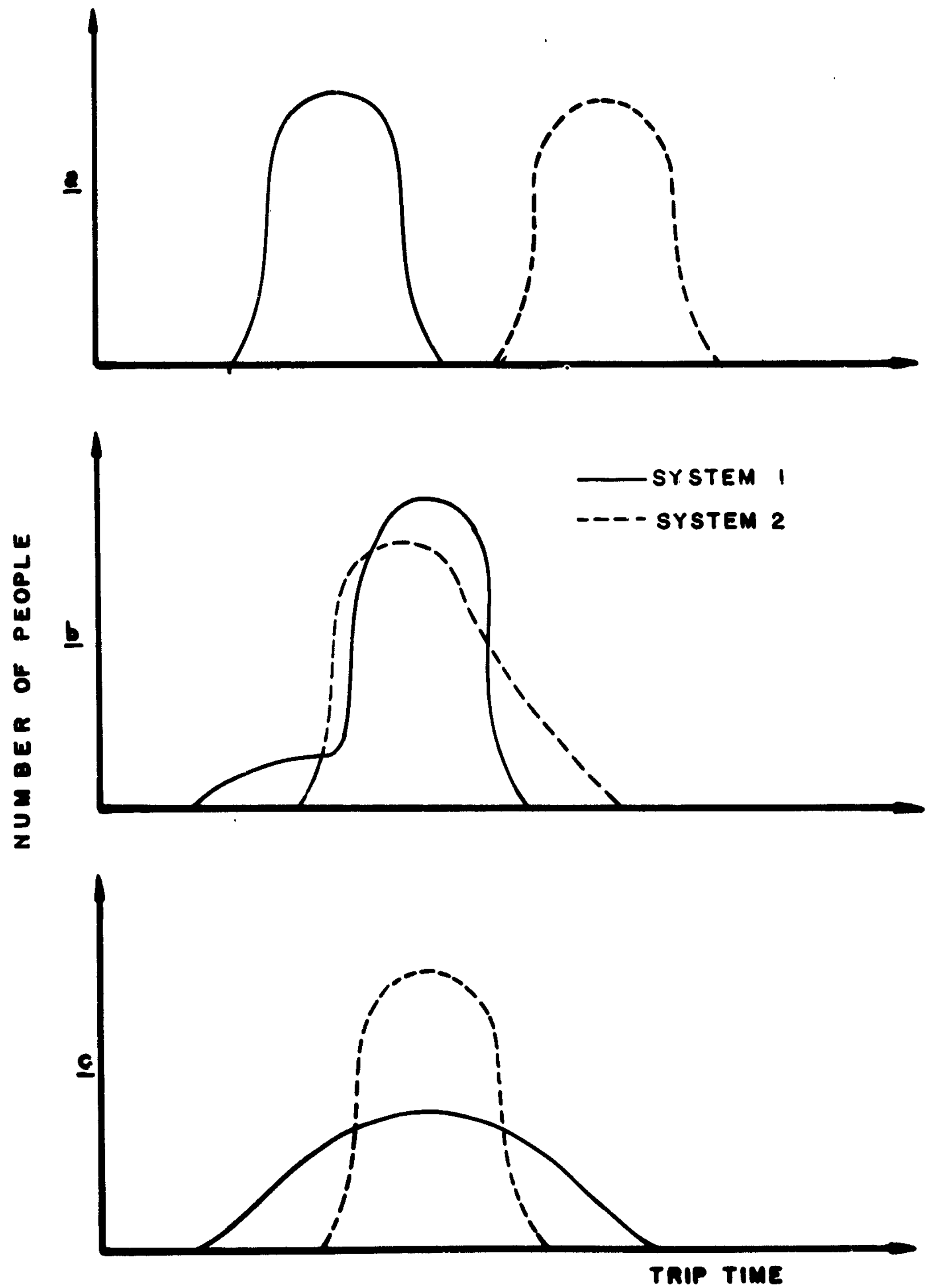
(3) Headway (this may be variable or it may be constant, and it may be dependent or independent on short range fluctuations in the number of passenger arrivals. Depending on the form it takes we can handle it appropriately for subsequent calculations).

We can consider a set of values on each of the three parameters listed above (for the present purpose, a constant value will be assumed for the third parameter, although a variable value could be handled) to define completely a transportation system for the purpose of any kinematic analysis to be performed upon it. That is to say, if we were to consider a run from point A to point B, and we were further to consider a transportation system which had 50-passenger vehicles, required an hour to negotiate the route from A to B, and operated on a 15 minute headway (schedule), we would have given a complete generic description of a transportation system operating from A to B. Regardless of how many physical forms such a system might take, if they were operating on a given kinematic requirement function (Figure III-3), they would produce identical kinematic performance functions (Figure III-4).

If we wish to compare two different systems, in this context, we have to compare the results of their respective generic parameters operating on the given requirements. The results of such a comparison, i.e., the comparison of the two concomitant kinematic performance functions (examples of Figure III-4), may give a clear superiority-inferiority measure in some cases, while in other cases they may not. Figure III-5(a, b, and c) show three ways in which such a comparison may turn out. In a system #1's kinematic performance curve is obviously better than that of system #2 because everybody would be transported by system #1 in a shorter time than anybody would be transported by system

FIGURE III-5

3 HYPOTHETICAL RESULTS OF COMPARING TWO REFERENCE FUNCTIONS



#2. The performance curves in c are not so obviously compared, however. Arguing from an intuitive point of view, if the first percentile[1] of system #1's people were transported in less time than the first percentile of system #2's people, and the first 2 percentiles of #1 were faster than the first 2 percentiles of #2 and so on, so that every one of #1's percentiles were faster than their corresponding members in #2, then there would be no reasonable bar to saying that system #1 transported the people faster than system #2. In Figure III-5 such a statement can be made about the two distributions in a, but it can not be made about c, and it may or may not be made about b, (depending on a close examination and comparison of the two performance curves.) For a situation as in c, an absolute criterion, #1 is faster than #2, or vice versa, can not be applied. For these and for other situations which we may wish to examine, we need a further consideration of criteria.

## Establishing Kinematic Criteria

Whereas for some comparisons it is likely that the performance functions will be so discretely different that interpretation offers no

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[1] We could extend the argument or definition beyond percentiles to limiting values as follows:

Let f(x) be the distribution function of system #1 either in Figure III-5 a, b, or c, and let g(x) be the distribution function of system #2 in the same member of a, b, c in which we have chosen f(x). Then we could state the distinction that system #1 is better (faster) than system #2 if

$$\int_0^x f(t)\,dt \leq \int_0^x g(t)\,dt$$

for all x, and the strict inequality holds for some value of x. The variable s here corresponds to time.

problem, it is not likely that there will be among the most frequent cases. In order to discriminate between two functions neither of which is obviously superior by direct comparison, it is possible to introduce a third reference to which each function can be compared. If this third reference can be interpreted as desired or required performance values, then whether, or how well, each function meets the desired values can be determined. The desired or required performance values are herein referred to as criteria.

There are at least two ways in which we could move to establish absolute kinematic criteria to be applied to system performance functions. We could specify that the mean of the distribution meet some certain predetermined time criterion, e.g., mean must not exceed 27 minutes. By so doing we are not concerning ourselves with whether or not large numbers of people have to take 40 or 50 minutes, just so long as the mean value was 27 or less minutes. On the other hand, it could be specified that some large percentage such as 95% or 99% of the passengers be transported within some criterion time, e.g., all passengers must be transported by the system in 35 minutes or less. By this method we are not recognizing or considering important differences which might exist between distributions, e.g., both might mean the criterion, but the mean of one might be much less than the mean of the other.

These two approaches, different as they may seem, differ more in degree than in kind, and can easily be combined. For example, both a ceiling which X% of the distribution must fall below, and also a ceiling

which the mean, or nth percentile, of the distribution must fall below can be specified.[1]

These are forms in which a criterion may be stated. They may be regarded as merely a structure or framework for the establishment of a criterion. Nothing stated here can be construed as a means of determining just what values the criteria should take. What has been stated is a reasonable set of methods by which we may make as precise as we wish any statement of criteria whose values are given from some external source. How particular values are established in a given case is not a matter of concern at this point because the method described will handle them regardless of their source.[2]

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[1] As many more percentiles and corresponding criterion values which the tested distribution must not exceed could be added as appeared feasible. As more percentiles and criterion values are added, in effect, criterion distribution would result. The distribution we are investigating would have to stay within it in the same absolute sense as we described in the preceding section.

[2] However, at least two different means of determining criterion values might be mentioned.

a) Existing transportation systems might be taken as standards or "yardsticks". For example, criterion values could be established by requiring a 10% increment in the performance function for the best existing system. Any number of reasonable rules could be applied to a standard existing performance function to generate criterion values.

b) Conduct psychological experiments with air travelers to determine a set of criterion values based on subjective preference. This could be approached in a number of ways. For example, a curve of indifference between fare and time ( a set of points on fare and time coordinates at which the passenger is satisfied that trip time is worth the fare paid) could be likewise established. The time equivalent of the maximum fare could be reasonably taken as a criterion value. Although oversimplified here, this method offers considerable promise.

## A Mathematical Model of System Kinematic Functioning

What has been described up to this point are the essential elements of a mathematical mode of the kinematic functioning of a transportation system. Such a model is formalized in Part IV of this report. Through its use in high speed computers, it enables the mathematical simulation of the kinematics of any system. The model has many potential uses, but its prime use, for present purposes, is to generate performance functions for any system we wish to examine. To employ the model for this purpose, the data required are the following:

(1) Kinematic requirements--a set of passengers--over-time functions, one for each pair of points being considered, which specify the load to be carried at the particular airport being examined.

(2) Capacity--the number of people carried by each vehicle being considerd. In a real situation, this is likely to prove a complex matter, especially where there are vehicles of different capacities in the same system and where capacity of the vehicles used may vary with some other variable, *e.g.*, time of day. Nonetheless, while at times complicated, it is possible to specify capacity for any system.

(3) Headway--the time interval between successive vehicle traveling between the same two points. A system may be regularly scheduled, irregularly scheduled, unscheduled or a combination of any of these. For unscheduled operations, the rules governing a departure, or the departure discipline ultimately reduce to the same thing, the specification of the time between successive vehicles.

(4) Travel time--the time it takes for the vehicle to travel between the two points involved. Again, this may require a very complex expression to take into account the many factors which may cause travel time to vary.

Given the above data, the kinematic performance function of any system can be generated by mathematical simulation procedures (Monte Carlo).[1] One such procedure suitable for use in a digital computer is presented in Part IV.

Summary

Our problem has been one of examining the kinematic factors of transportation systems in order to discern generic parameters suitable as bases for the comparative evaluation of two or more systems designed to perform the same task. The examination disclosed certain inherent relationships which obtain among load, capacity, headway, travel time and trip time. Means were described by which:

> The ability of a system (of given capacity, headway, and travel time) to move a given load to given locations can be measured by the distribution of load over trip time (performance functions) it produces.

The performance functions of any two systems can be compared with each other and/or with a given criterion. Thus, the evaluation of systems in terms of kinematic factors appears to be feasible.

In Part IV, the model is described in formal terms and a flow diagram is presented.

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[1] Bulk service queue techniques appear to be potentially useful for this purpose and further investigation is warranted. If and where they can be used, this would provide an analytic, as opposed to a simulation method of generating a performance function.

## Chapter 2. Engineering Factors

The kinematic factors discussed in the previous chapter concerned the requirements which must be fulfilled by whatever system is used. In this section, we turn to the physical characteristics of the system itself. Essentially we are seeking ways of describing the system such that the terms of the description are generic to any system and relate to the system's ability to fulfill the kinematic requirements.

### Historical Review

A historical review of the life cycles of transportation systems reveals a correlation which exists between technology and the success of such systems. Technology has been the fundamental determinant in the initial rise of every transportation system (excepting those involving beasts of burden), and it has remained as an important factor, sometimes the prime factor, in the subsequent early development of each system. However, as systems have matured, the rate of technological advance has tended to slow down markedly. The ultimate fate of many systems seems attributable to the stagnation of technological developments.

Technology also appears to be the fundamental determinant in the demise of transportation systems, both in a negative and in a positive sense. In a positive sense, the somewhat glamorous technology of a new system with its popular support permits it to gain technological advantage rapidly over the more established systems. In a negative sense, the neglect of continued technological development in established systems has tended to prevent them from continuing their competitive positions against new developments.

The rapid rise of the railroads in the first half of the 19th century was brought about by a breakthrough in technology which opened up and satisfied an enormous transportation demand. Technology rapidly progressed in the formative stages of the system, and the railroad became firmly established throughout most of the civilized world as the major means of land transportation. This rapid growth continued despite almost careless disregard of other considerations. As the railroad systems matured, however, their technology became static and finally subsided to a function of maintenance and faltering minor development. Their robust technology had disappeared. Although railroading today represents great operational advancement over what it was 100 years ago, the advance has been in details and detail refinements.

In the late 19th and early 20th century, the inter-urbans were suddenly developed and rapidly covered the country. They were spawned by a dynamic and new technology and soon found their place as one of the major means of transportation of both persons and goods. They represented a new achievement in average speed and city-center to city-center elapsed times for inter-urban travel. Frequent stops provided superior convenience, and low fares, as compared to the railroads, further enhanced their popularity. The inter-urbans matured rather rapidly and thereafter the growth in their technology seemed to diminish. Only minor advances in technology followed the period of their peak success. When the motor bus and the automobile were introduced the static technology of the inter-urbans could not meet the challenge and they soon left the scene. In a similar fashion, trolley cars for city transit fell prey to the motor bus and now the motor bus is giving way to the automobile.

At the present time, air transport is enjoying enormous growth and its technology is still one of the most important, perhaps even the prime factor in this popularity. Air transport had a slower rise than either the railroad or the inter-urban. For many years it was considered more or less an engineering curiosity rather than a serious means of transportation. Recently, however, its technology has brought it to a position of great utility and its success, as is well known, has been spectacular. The extent to which its success can be expected to continue will depend, in part, upon whether it follows the path of previous systems or continues to spur on technological advances to meet the competition which will surely arise.

It is not reasonable to contend that technology alone accounted for the rise and decline of various transportation systems. Nonetheless, as one important factor, the apparent correlation between rate of technological development and the subsequent competitive position of the system can not easily be ignored. In some cases, it is probably true that certain inherent limitations precluded further real development. A case in point is the inter-urban which succumbed quickly to the suburbia it helped create. However, one could only conjecture as to the present position of the railroads if their rate of technological development before 1900 had been maintained afterward.

New developments are taking place within the air transport field itself which already threaten conventional fixed-wing aircraft, especially in the short-haul range. These developments, of course, embrace the vertical or short-takeoff and landing type craft. Perhaps these developments should be considered as representative of a continuance of a still-vigorous airborne transportation system technology rather than viewed as competitive with fixed-wing aircraft.

Technology, in the case of the automobile transportation system which is currently the greatest means of mass transportation, is still on the rise and the pattern so far is typical. The development of an extensive system of public roads is, however, a limiting factor which must be considered. The advances in technology of the automobile itself are not nearly as spectacular as that of aircraft. However, regardless of the significance of the technological aspects of the automobile these achievements could not have been made fruitful for public use expect through the development of the streets, roads, and highways systems which now exist and which are increasing at a great rate. Therefore, consideration of the development of the automobile as a means for mass transportation must include consideration of the development of the highways on which the automobile rides. The automobile and its highways are still in the early stages of development, but already it seems clear that continued growth of the automobile and highways along present-day lines will lead to a diminution of the advantages to which the automobile owes much of its popularity. The rate of increase in use of the automobile is far outstripping the roadbuilding required to accommodate the increase. And the limits to which roadbuilding, in its present form, can go are not faraway.

## Engineering Parameters

Engineering factors are herein defined as those factors which can be evaluated or controlled by proper application of the physical laws of nature to appropriate components of a transportation system. Factors included in this classification are:

| | |
|---|---|
| capacity | noise |
| speed | vibration |
| power | cleanliness |
| range | appearance |
| reliability | accessibility |
| all-weather capability | privacy |

The first six of the above parameters determine the ability of a system to satisfy the load, distance, and time requirements (i. e., the kinematic performance of a system). The last six parameters are more related to psychological factors--those which provide satisfaction to the passenger. Although these factors all have engineering implications, they will be discussed under the chapter on psychological factors. All of these parameters are related to the system costs in that design improvements in each of these technological factors may alter the cost of the system.

A successful transportation system must meet the primary system requirements of load, distribution, and time with high performance, low cost, and as much passenger satisfaction as possible.

Capacity is a measure of the payload of the vehicles, way, subsystems, and systems. Vehicle capacity is defined herein as the number of passengers the vehicle can carry. Way capacity may be expressed as the number of vehicles carried per unit time. System capacity is determined by the vehicle and way capacities combined, and may be expressed as the number of passengers carried per unit time.

Speed is a characteristic of the system which relates directly to travel time. Although the speeds usually specified in the design of vehicles are maximum speed or cruising speed, the speed of interest in the present problem is the average speed. The average speed may be

a function of the vehicle, the way, traffic congestion, stage length[1], and weather. Although speed is not usually considered to be a characteristic of a way, past experience has shown that certain types of ways exhibit speed capabilities independent of the characteristics of the vehicles. It is reported, for example, that average journey speeds on rural highways have increased from 26 to 50 miles per hour during the past three decades ( 63 ). The fact that there has been no such increase in speeds on city streets indicates the effect of traffic congestion. The speeds which may be attained on most ground ways are determined by traffic congestion and stage lengths rather than by vehicle capabilities. This may or may not be true in the case of helicopters or other V/STOL aircraft which can accelerate rapidly to cruising velocity and which are not delayed by other ground traffic. As their numbers increase, however, air traffic may become congested as well.

The power required to operate a transportation system is one indication of system performance. Power is dissipated in overcoming the inertia of an accelerating vehicle and the drag (ground and air) of a steadily moving vehicle. Power is also required to supply the necessary lift for an airborne vehicle. The power required to move a vehicle is equal to the product of the force applied and the speed with which the vehicle moves (i. e., $P = FV$). Since the inertia force is equal to the product of the mass of the vehicle and the vehicle acceleration (i. e., $F = ma$), the power required for acceleration varies directly with the mass, acceleration, and velocity. The ground drag force is proportional to the vehicle mass; hence, the power required to overcome this

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[1] Stage length is defined as the distance between two consecutive scheduled stops of the vehicle.

force varies directly with the vehicle mass and velocity. Air drag is proportional to the square of the vehicle velocity (i. e., $F \sim V^2$); therefore, the power required to overcome air drag varies directly with the cube of the vehicle velocity. Hence, it is evident that high acceleration and high speed may be "purchased" by the expenditure of great amounts of power.

Good transportation systems are, of necessity, reliable systems. Patrons expect transportation system vehicles to arrive and depart on schedule, or they cease to patronize such systems. Reliability may be provided by a combination of proper design, preventive maintenance, and application of the principle of "redundancy" (i. e., by the provision of duplicates of unreliable components). One of the objectives of proper design, which is the most efficient means of assuring reliability, is simplicity. The more parts, or components, involved in a system, the more likely the system is to fail. Hence, a complex system requires an extensive duplication of unreliable components, or a very frequent schedule of preventive maintenance involving the efforts of many specialized skills.

No transportation system can be completely desirable unless it has all-weather capability (i. e., its performance is relatively unaffected by changes in weather conditions). Such a capability is a desirable quality which can be provided by proper engineering. No system currently in existence has complete all-weather capability, but some are less vulnerable to inclement weather than others. Railroad systems are probably the least affected by weather. Systems utilizing "rubber-tired" vehicles are capable of movement in most types of weather, but only at reduced speed. Airborne systems are usually the most restricted by bad weather.

Until just recently, helicopters were not licensed to fly under instrument conditions; light fog, rain, or snow could result in disruption of service. However, recent technological achievements in air traffic control systems have made all-weather capability a possibility for nearly all aircraft.

Safe transportation must be provided by any successful system. Certain steps which are outside the realm of engineering can be, and have been, taken to assure the safety of passengers. These include laws and regulations, and safety education of the passengers. However, safety is one of the major engineering considerations in the design of transportation vehicles and ways. Many engineering steps have been taken to provide safer automobiles for the motoring public. These include padded dash-boards, seat-belts, stronger bodies, better brakes, and "deep dish" steering wheels. Airplanes have been equipped with seat-belts ever since their successful operation. Many studies have been conducted and sponsored by industry and government to develop engineering techniques to improve the safety of transportation. Many of the results of such studies have yet to be applied because of the anticipated lack of public acceptance. Past experience has shown that certain types of transportation subsystems are safer than others. The automobile, our number 1 killer, is reported as exacting an annual toll roughly one hundred times greater than that of airplane and rail accidents combined (377). Safety will continue to be a major engineering requirement in the design of transportation systems.

## Quantification of Engineering Factors

Preceding paragraphs have been devoted to a qualitative discussion of the engineering aspects of airport transportation systems. The present section is devoted to a discussion of various means of deriving quantitative indices for each of the previously discussed engineering factors.

Transportation systems are composed of combinations of vehicles operating on specific ways. It is possible that several different types of vehicles operate on the same way; e. g., automobiles, taxis, and buses may all use the same expressway. On the other hand, some vehicles may have an exclusive way--such as a rapid transit train. The types of vehicles and ways which may logically be considered for a transportation system are determined by the problem the system is designed to solve. The vehicles which are logical possibilities for consideration for airport transportation at the present, or in the near future, appear to be the following.

| | |
|---|---|
| Private automobile | Trolley |
| Taxi | Rapid rail |
| Limousine | Monorail |
| Bus | V/STOL aircraft |

Extremely advanced vehicle concepts, such as Ground Effect Machines and Levacars, are excluded from consideration at the present because of insufficiency of engineering data.

A distinction can be made between what we might call uni-link trips and multi-link trips. If the passenger's trip is conceived as being between the airport and his local origin or destination (which potentially is anywhere within a wide radius of the airport), then some vehicles offer the possibility of door-to-door transportation, a uni-link trip; and other vehicles, for the majority of origins and destinations, will require that part of the trip be made by some other means, a multi-link trip. Taxis, automobiles, and limousines offer the potential of uni-link trips.

One possible definition of a performance index assigns a numerical value to each system component which is equal to the capability of that

component. For example, with such a definition the capacity index of the S-55 helicopter is 12, and the speed index is 85 miles per hour. The performance of some types of transportation system components can be best specified in terms of parameters which are combinations of the performance parameters previously listed. In such cases, the performance indices are more meaningful and useful when defined in terms of the combined parameters. Gross power requirements, payload power requirements, and working rates are examples of such combined parameters. The gross power requirement of a given vehicle is defined as the ratio of the vehicle gross weight and the horsepower required to move the vehicle at a given speed. Payload power requirements are similarly defined, but are based on payload weight. The working rate of a vehicle is the ability of the vehicle to move a given payload, a given distance, in a specified time interval with a certain horsepower.

Vehicles and ways have significance from a performance point of view only when considered in logical combinations. Automobiles, taxis, limousines, and buses are significant transportation system components only when considered with roadways. Rapid rail trains and monorails must be considered with the trackway, and airborne vehicles together with their terminals and the airspace through which they travel. Such combinations of vehicles and ways may be considered as transportation subsystems.

The operating capacity of a vehicle way subsystem is expressed as the number of passengers carried per unit time, and can be determined from the vehicle capacity and the way capacity. For instance, the capacity of an automobile-freeway system might be determined as follows.

Automobile capacity = 4 passengers

Expressway capacity = $\frac{50,000}{24}$ vehicle/hr.

Subsystem capacity = 8,332 passengers/hr.

Average load of the subsystem can be determined by multiplying the subsystem capacity by the vehicle load factor.

$$\text{load factor} = \frac{\text{average number of passengers carried}^{1}}{\text{capacity}} = \frac{1.5}{4} = 0.375$$

average load = 8,332 x 0.375 = 3,210 passengers/hr.

Similarly, the capacity and average load of a helicopter transportation subsystem may be determined from the capacity of the helicopters used, the load factors attained, and the number of helicopters which can be handled per unit time by the airways.

The speed of a transportation subsystem can be determined by the characteristics of the way, the characteristics of the vehicle, or a combination of both. An auto-roadway subsystem would appear to be in the former category. Automobiles presently are capable of speeds in excess of 100 miles per hour on a modern, untraveled highway; however, the best expressways available are able to carry automobiles at average speeds of approximately one half that figure because of traffic congestion that prevails (215). Similar statements may be made for other types of rubber-tired vehicles. For example, buses capable of cruising speeds of sixty

[1] The average number of passengers per automobile has been determined to be approximately 1.5 persons.

miles per hour have been found to be able to travel at average speeds of less than ten miles per hour when put into service because of the existing traffic congestion along the assigned routes (125). Helicopters, or other V/STOL aircraft, may be examples of the other extreme, at least as currently utilized. The speeds attainable, at present, by helicopter subsystems are virtually unrestricted by the airways. Instead, the average speeds maintained are determined chiefly by the cruising speed of the vehicles. Average speeds for the helicopter, however, are normally only for one link of a passenger's multi-link trip.

Power has been shown to be a function of speed and acceleration; hence, high speed and acceleration are attained by the expenditure of great amounts of power. The gross power requirements per unit gross weight for various types of transportation subsystems are shown graphically in Figure III-6 as a function of speed. A power performance index for any vehicle subsystem is obtained by calculating the gross power requirement from the vehicle gross weight and the average vehicle velocity. The payload power requirements are determined from the capacity, power, and range for a given vehicle velocity. Typical payload power requirement curves are shown graphically in Figure III-7. The over-all performance efficiency of a transportation system is indicated by the working rate of the system; i. e., the ability to move a given load, a given number of miles, in a given period of time, with a given amount of horsepower. The working rate of a system, subsystem, or a component may be obtained from the cruising speed and the payload power requirements. Typical curves of working rates versus range for various types of transportation components are shown in Figure III-8.

FIGURE III - 6

GROSS POWER REQUIREMENTS

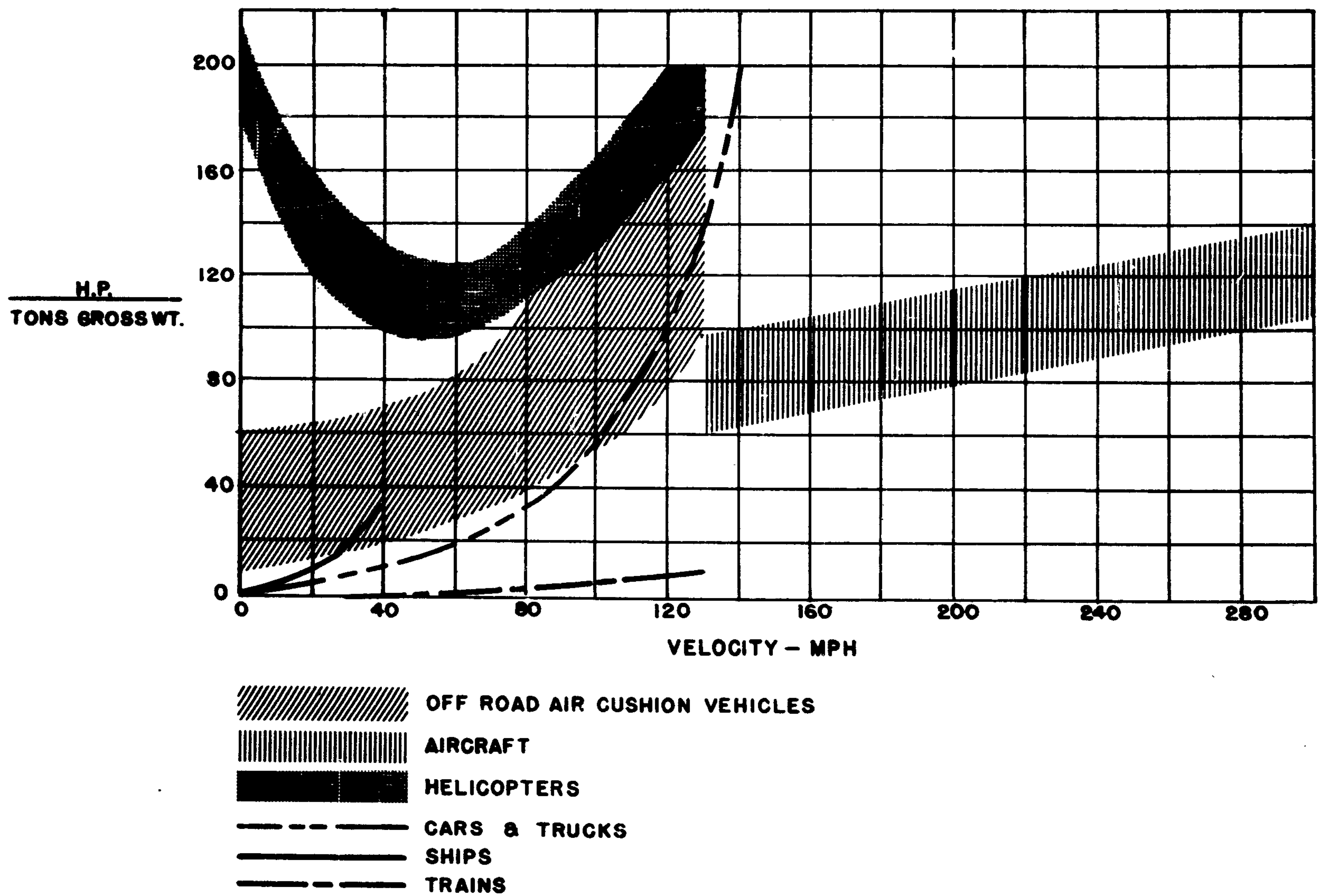
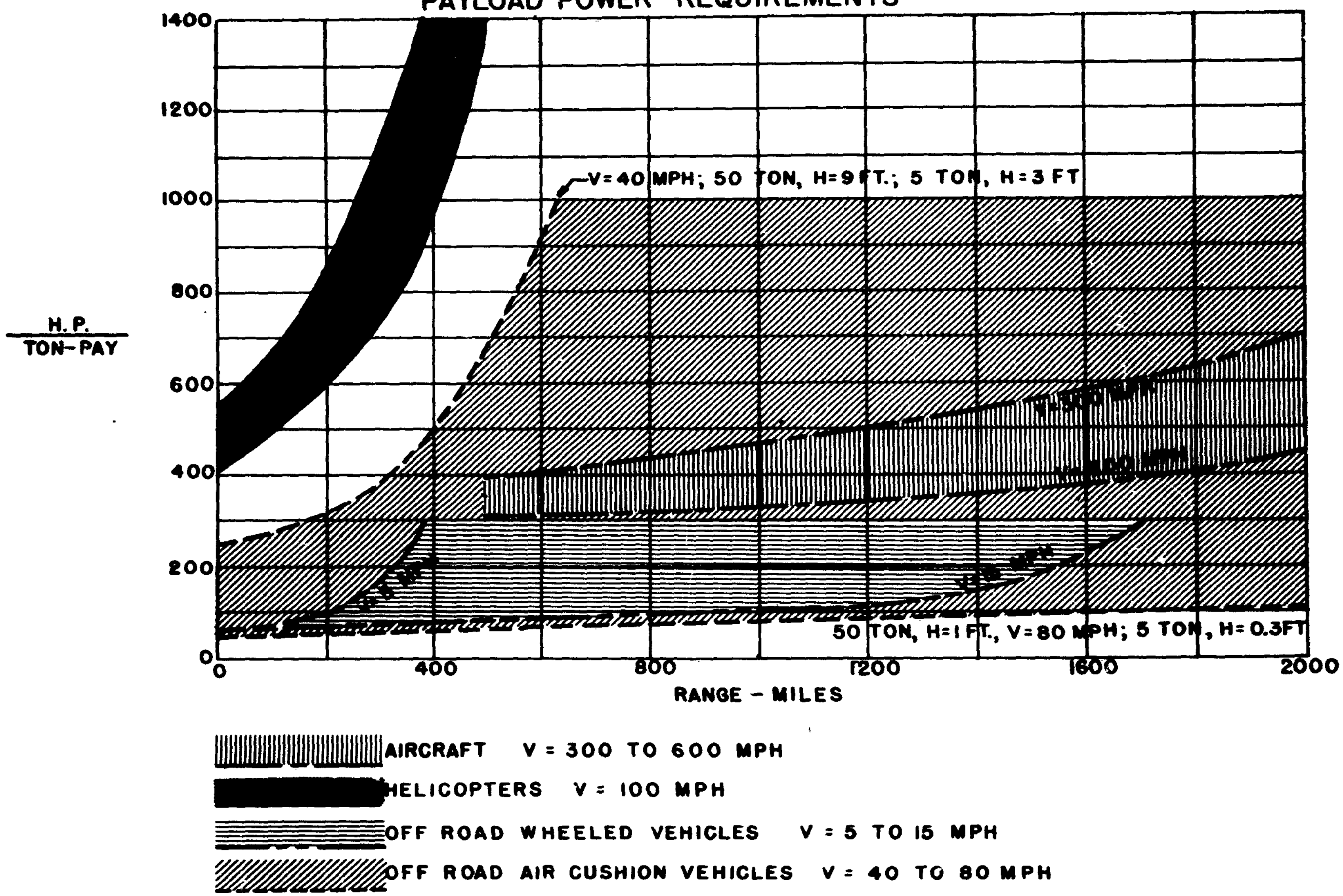
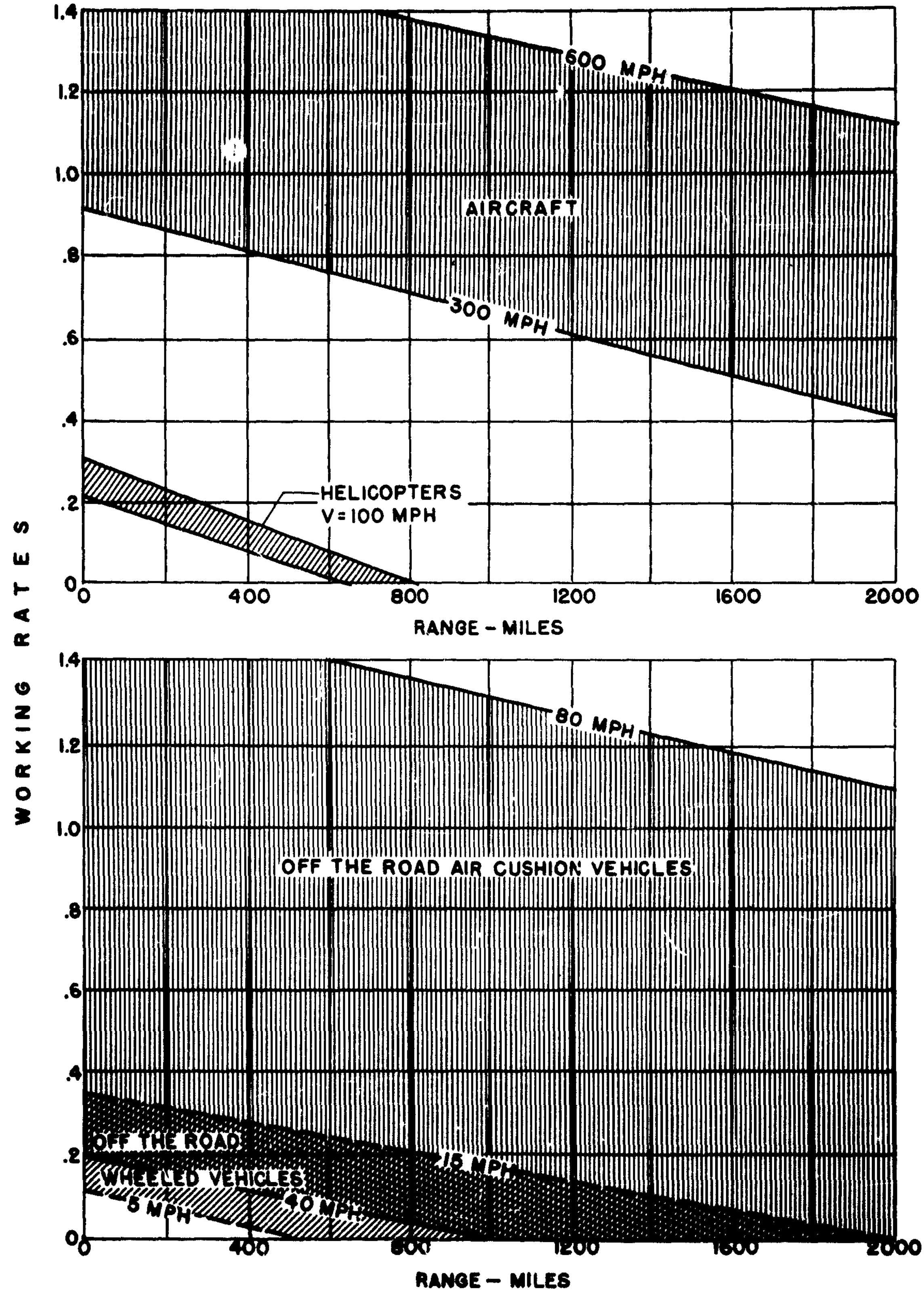


FIGURE III - 7

PAYLOAD POWER REQUIREMENTS



## FIGURE III - 8
## WORKING RATES



The safety of a transportation system is probably best reflected by the accident rate per passenger mile traveled. Accident statistics for existing systems are quoted for various types of accidents; i. e., property damage only, property damage and personal injury, and fatal injury. Since safety regulations are established to prevent personal injury as well as death, it would be desirable for a safety index to be based upon accident rates which involve personal injury requiring hospital treatment. Although it would be desirable to have accident rate data for system comparisons, it does not appear to be feasible. Accident rate data comparable from system to system represent a problem area in itself beyond the scope of the present project to consider in detail. It was not pursued further because of the limited value of accident rate data for present purposes. Since it is necessarily actuarial, for systems not yet in-being no such data can be provided. And comparison with proposed systems is the most frequent reason for evaluation; accident rate data, therefore, have been omitted from consideration.

The preceding paragraphs have discussed possible definitions of quantitative indices by which the performance of a transportation system, or its components, may be evaluated. Quantitative indices for capacity, average load, speed, power, range, and various combinations of these parameters have been suggested. Gross power requirements, payload power requirements, and working rates have been discussed. Since working rates reflect the importance of all four of the above parameters, and since such rates can be defined for all vehicle way subsystems, it is suggested that a single performance index for these parameters be defined in terms of working rates.

## Specification and Presentation of Required Data

Previous sections of this report have discussed the engineering factors involved in the design of transportation systems. These factors have been discussed both qualitatively and quantitatively, and the definitions of quantitative indices have been suggested.

The data required for determination of the various indices are specified by the tables and charts included in this section of the report. Those data that were currently available are included as exemplary entries in the tables and charts, and will undoubtedly require review and modification for an analysis of a specific airport-city complex. The tables and charts, many entries of which are missing because they are not readily available, are included because of the clear and concise manner in which they state the data and calculation requirements. One of the first steps in the treatment of any specific transportation complex will be to obtain the data that are missing from the tables and charts, and to revise, if necessary, the data that are presented herein.

The performance indices of any transportation system or subsystem are obtained from the performance characteristics of the vehicles and ways. These characteristics for the vehicles are summarized in Table III-1. The vehicle capacity is the maximum number of passengers the vehicle can carry, while $P_{ave}$ is the average number of passengers actually carried per vehicle. $V_a$ is the average speed maintained, and $P_{req}$ is the power required at the cruising speed ($V_c$) of the vehicle. $V_a$ and $V_c$ generally differ because of the "terminal time" which is included in the calculation of $V_a$. The time $T_L$ is that devoted to the loading and dispatching of vehicles at the terminals. The data presented for various vehicles will require review before application in the solution of any

## TABLE III-1

### Measures of Vehicle Performance

| Vehicle | Capacity (No. of Pass.) | $L_f$ | $P_{ave}$ (No. of Pass.) | $V_{ave}$ (mph) | $P_{req}$ (Hpwr) | $W_g$ (lb) | $T_L$ (Min.) |
|---|---|---|---|---|---|---|---|
| Automobile (63) | 5 | 0.300 | 1.5 | | 100-200 | 2500-5000 | |
| Expressway | | | | 50 | | | |
| Urban Street | | | | 20 | | | |
| Taxi (63) | 4 | 0.375 | 1.5 | | 150 | 3000 | |
| Expressway | | | | 50 | | | |
| Urban Street | | | | 20 | | | |
| Limousine | 12 | | | | | | |
| Expressway | | | | 40 | | | |
| Urban Street | | | | 15 | | | |
| Bus (373, 125) | | | 23 | | | | |
| Expressway | | | | 40 | | | |
| Urban Street | | | | 10 | | | |
| Rapid Rail (373) | | | 22 | | | | |
| Monorail | | | | | | | |
| Los Angeles | 80 | | | 70 | | | |
| Seattle | 64 | | | 60 | | 16,000 | |
| Paris | 32 | | | 60 | 400 | 22,000 | |
| Helicopter (430, 436) | | | | | | | |
| S-55 | 8 | | | 85 | 600 | 6,800 | |
| S-58 | 12 | 0.51 | 6 | 100 | | 12,700 | 2 |
| S-61 | 25 | | | 130 | | 18,000 | |
| V-107 | 25 | | | | | | |
| Rotodyne | | | | | | | |
| STOL (107) | 50 | | | 285 | 10,000 | 53,000 | |

particular problem. The average speed of the taxi is assumed to be the same as that of the private automobile, and that for the limousine was arbitrarily reduced from the automobile data to account for the time devoted to loading and discharging passengers at intermediate stops. The various data shown for monorail are those anticipated for designs for Los Angeles, Seattle, and Paris; and those shown for STOL are based on a hypothetical vehicle.

The way performance data summarized in Table III-2 are capacity, expressed in vehicles per unit time, and headway, expressed in units of time. The capacity of any vehicle way subsystem is determined by the vehicle capacity in conjunction with the way capacity, permissible headway, or vehicle loading time. Each of the latter three items limits the number of vehicles per unit time on the way, and that which fixes the lowest limit is the deciding factor to be used in the determination of system capacity.

Power requirements indicative of the efficiency of a transportation system are presented. Gross power requirements are calculated from the vehicle gross weight and the total power required. The results of those calculations are presented in Figure III-9. Gross power requirement curves have been shown previously in Figure III-6 as functions of speed; however, since the vehicles will be operating at or near the cruising velocity, the power requirements are calculated for cruising velocity only. Payload power requirements are obtained in a similar manner from the payload weight and the power required, and are shown in Figure III-10. Payload power requirements were previously shown in Figure III-7 as functions of range. However, since the present problem involves only short-range trips, the payload power requirements shown in Figure III-10 are assumed to be independent of range.

FIGURE III - 9
GROSS POWER REQUIREMENTS

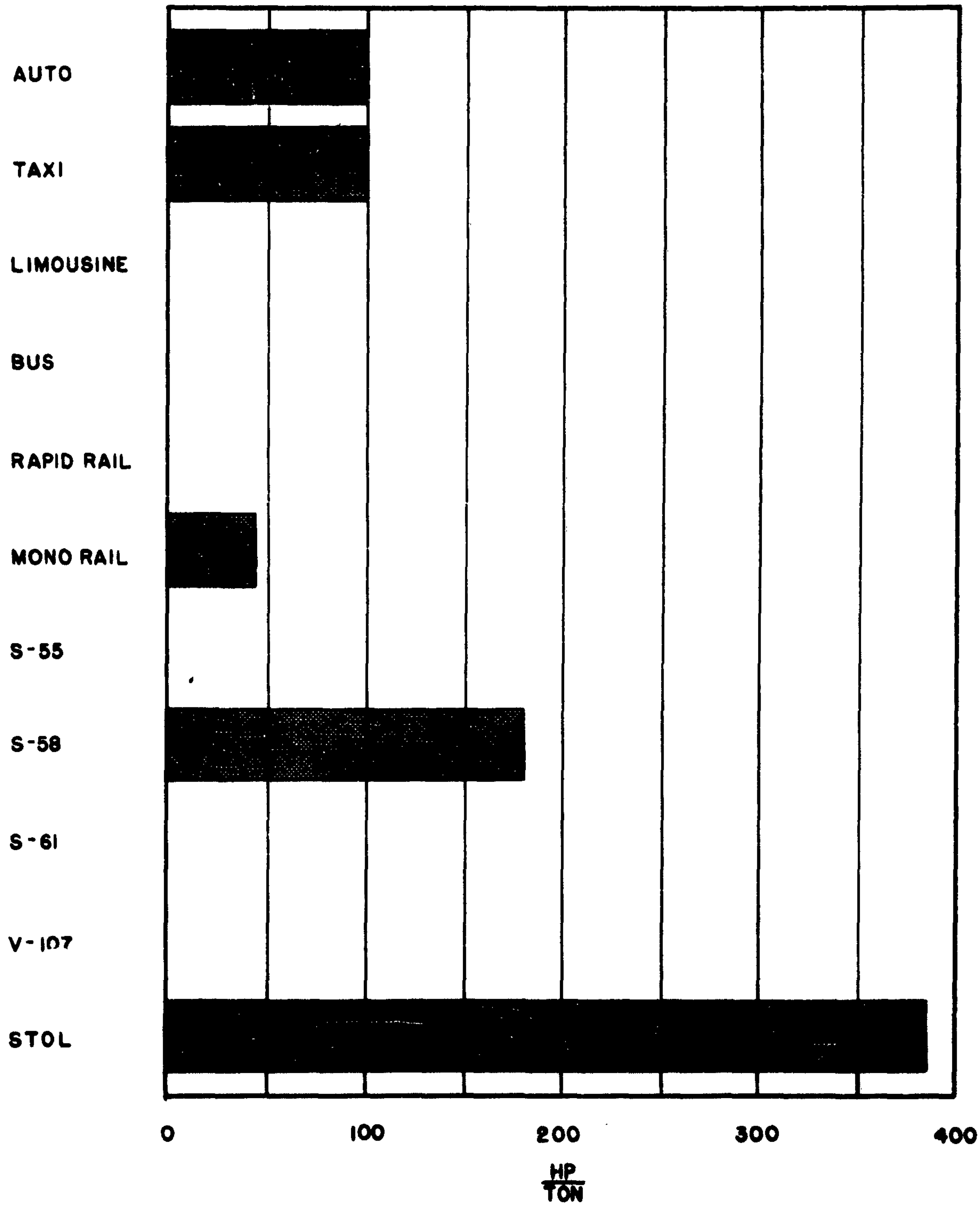
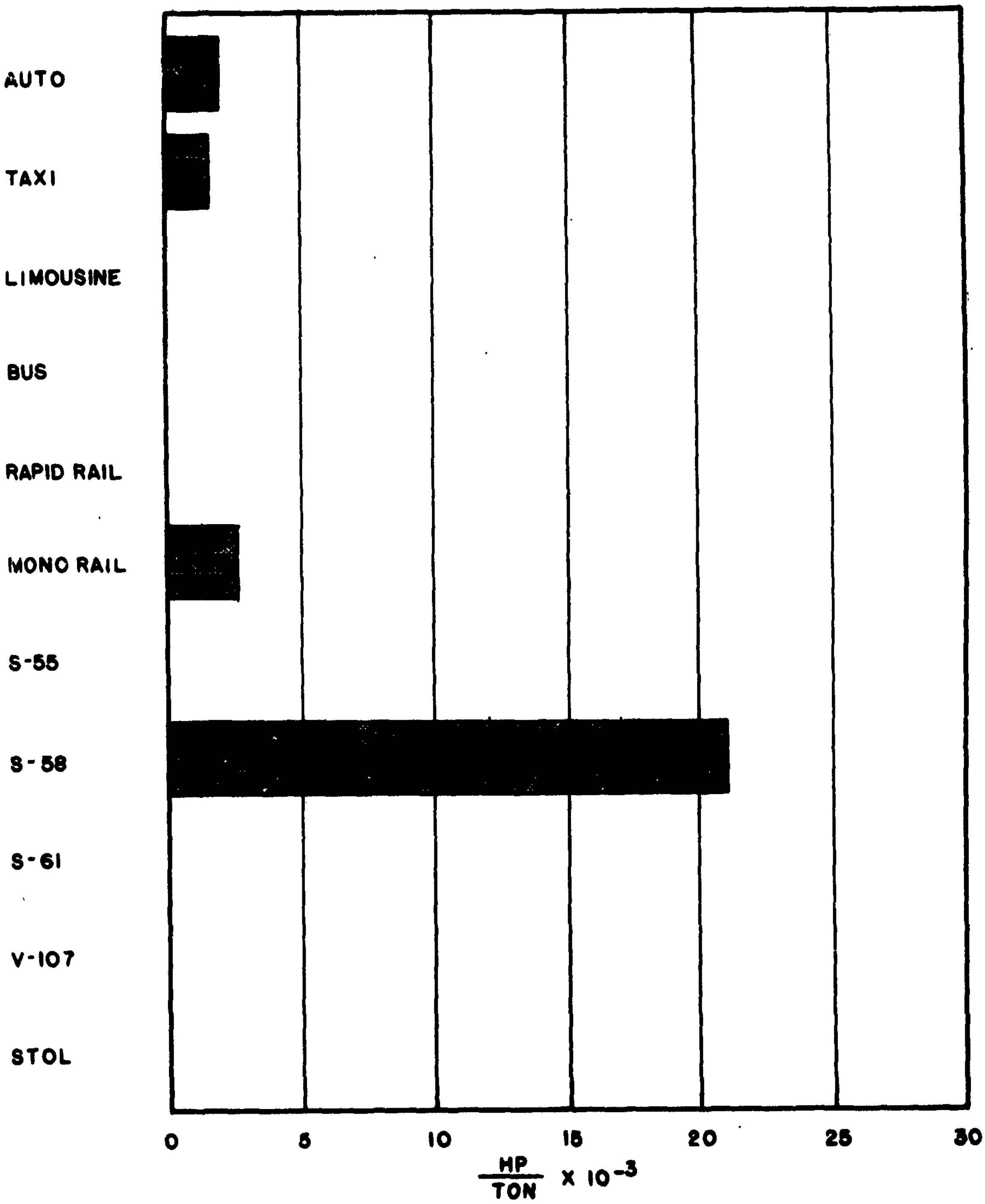


FIGURE III-10
PAYLOAD POWER REQUIREMENTS



## TABLE III-2

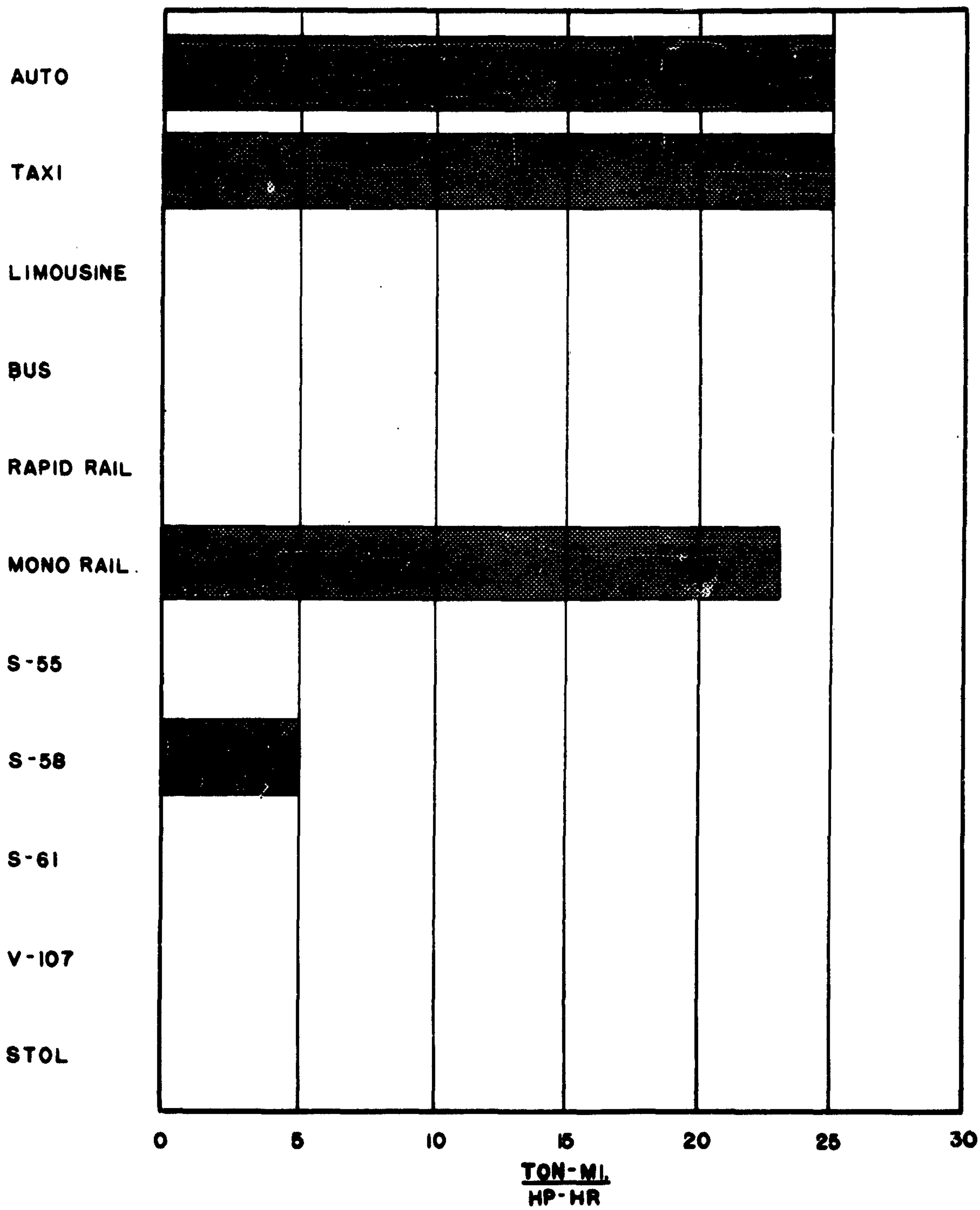
### Way Performance

| | Capacity (Veh/ day) | Headway (minutes) |
|---|---|---|
| Expressway (63): | | |
| 2 lanes each way | 50,000 | 0.17 (10 seconds) |
| 3 lanes each way | 110,000 | |
| 4 lanes each way | 160,000 | |
| Urban Street (63): | 7,200 | |
| Rapid Rail: | | |
| Monorail: | | |
| Airways: | | |
| Helicopter (384) | 100 | |
| Rotodyne | | |
| STOL | | |

Note: Per airstop with one TO area

Working rates are generally good measures of over-all efficiency of a transportation system, and such rates are shown in Figure III-11. These rates are obtained by dividing the payload power requirements by the cruising velocity, and therefore are also independent of range.

FIGURE III-11
WORKING RATES



# Chapter 3. Economic Factors

Airport transportation is an integral part of the over-all transportation problem in metropolitan areas and as such it is necessary to consider first some of the economic aspects of transportation in general in order to identify those factors critical to airport transportation.

Even though much of today's economic efforts in labor, capital, and managerial ability is devoted to supplying transportation service, and even though a large share of today's income is spent in paying for that service, problems of transportation have generally not been critical in the field of economics in the past and there has been little theoretical development in transportation economics. There is considerable lack of consensus about many areas in transportation economics among economists, engineers, accountants, and public-finance experts (166, p. 14). No attempt will be made to take sides in the arguments existing among various authorities but, rather, the aim is to review the present state of knowledge for the purpose of discovering those parameters which can be used for objective, comparative evaluation of airport transportation systems.

The conclusions at which we arrive are somewhat different from what one might expect and it is, therefore, encumbent on us to be as clear as possible as to how we arrived at them. In the first section, a set of basic economic concepts are defined to provide the tools for the delineation of economic factors of airport transportation in the following section. From these, certain economic parameters are devised in the final section.

## Time and Place Utility

Utility is traditionally defined in economics as "want satisfying power". Time and place utility can be defined as the want-satisfying power possessed by a person or good at a given time at a given place. Transportation creates time and place utility for people and goods by delivering them in good physical shape at a given time and at a given place when and where their presence is most wanted.

Transportation is capable of satisfying wants both indirectly and directly. Indirectly, transportation is instrumental to the satisfaction of wants requiring the movement of people or things. Direct satisfaction of wants occurs in the case of travel for the sake of travel.

The exploitation of the advantages offered through the creation of time and place utility is one of the greatest competitive assets of air transportation. Airport transportation is part of the over-all effect exerted on time utility by air transportation. Thus, in this context, the problem of the present research could be stated as the investigation of the effects of airport transportation on time utility.

## Transportation Units

The most commonly accepted transportation units are the ton-mile and the passenger-mile, defined as the movement of 1 ton of cargo or 1 passenger over the distance of a mile. The movement of 5 tons of freight, or 5 passengers over the distrance of 10 miles would result in a 50- ton mile, or 50-passenger mile trip. Cost reduction for ton-and passenger-miles in the past has resulted from changes in: (a) the shape of the vehicle (streamlining), and (b) the efficiency of means of propulsion (better and more powerful engines and motors).

## Ways

A way is defined as the medium, surface, or structure through or on which a transportation vehicle moves. The type of way used provides the most fundamental distinction between modes of transportation. These are the following.

(1) Air;

(2) water;

(3) rail;

(4) highways.

With respect to (1) and (2), the expenses involved for the carriers are the costs of the facilities (airports and harbors, etc.) but, except for the terminal points, the ways themselves are free. The carriers pay for terminal facilities in fees, tolls, and special taxes (e. g., in 1959 a landing at Idlewild Airport cost 35¢ per thousand pounds of a plane's maximum allowable takeoff gross weight). The cost of these facilities is only part of the total costs that the carriers have to bear. Railways and highways, of course, have to be constructed in their entirety.

With respect to the cost considerations in the construction of ways, the following factors are of importance.

(1) Value of the strip of land (this depends on location and size).

(2) The nature of the terrain.

(3) Weight-bearing capacity.

(4) Grade.

(5) Curves.

Capital outlays are of greater importance in highway construction than are maintenance costs and the opposite is true for the railroads. The reason for this is that the United States highway system is still being developed, whereas the rail track system has been essentially completed a long time ago.

## Some General Cost Concepts

The primary purpose of economic considerations in this study is to help furnish one of the methods of evaluating the performance of airport transportation systems. Costs are of central concern in this endeavor and a brief recapitulation of the basic concepts underlying production and cost theory are in order.

The basic concept underlying cost theory is the cost function[1]. The cost function shows the relationship between costs incurred (expressed in a monetary unit) and quantity of outputs produced (expressed in output units of the good or service, such as passenger-miles).

Total costs are divided into fixed and variable costs. Total fixed costs do not react to changes in output, and variable costs vary directly in proportion to the volume of business (i. e., of the carrier). If total fixed costs and variable costs are divided by units of the total output, average fixed and average variable costs result.

Average fixed costs always decline with an increase in output. Average variable costs may remain constant, increase, or decrease with an increase in output. The increment to total cost due to an added output unit is the marginal cost. Customarily, the rate of change in variable cost is considered to be the marginal cost.

[1] The discussion following on pages 185 and 187 is based essentially on reference 267, pp. 18-27.

With respect to the above distinctions, short and long run time periods will also have to be distinguished. Short run generally means a period so short that there is no possibility of expanding (or contracting) plant size or heavy equipment. In the long run, which is a period long enough for plant size to vary, only variable costs exist and all of the above cost distinctions are superfluous. Instead of a two-dimensional cost function such as the one discussed previously, a third dimension is added in this case; i. e., each cost point has a plant size and an output dimension--thus a three-dimensional multivariable analysis results. A typical three-dimensional cost function is presented in Figure III-12.

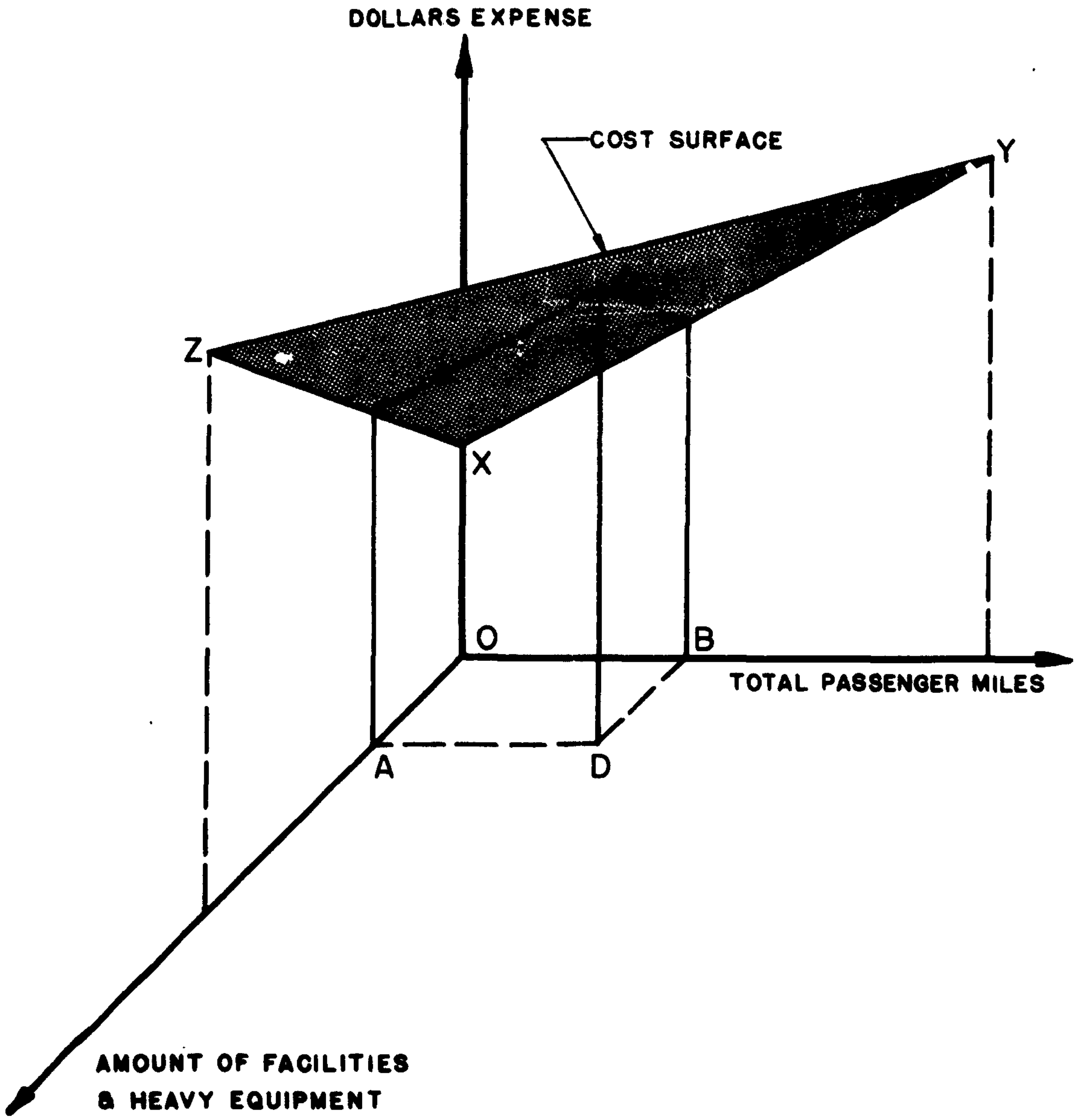
The cost function here is the plane rather than the curve or line used in two-dimensional functions. $\overline{OA}$, amount of facilities and heavy equipment, and $\overline{OB}$, passenger miles, result here in an estimated total cost represented by the line $\overline{DC}$. C is the point which on the cost plane is directly above D which represents the $\overline{OA}$, $\overline{OB}$ size-output combination. Thus, the essential difference between long and short run cost curves can be viewed as being related to the ability of varying the plant size.

The short run cost function can be considered as empirically describing the "full capacity" of a plant. Full capacity is generally considered to be that point at which the fixed assets are so thoroughly utilized that average total costs rise from some minimum average total cost point on.

Fixed costs can be viewed as those existing at a level where output is at or around O. This can be also interpreted to mean that certain costs have to be taken care of before operations enter the range of economic production; thus fixed costs can be viewed as threshold costs, which are represented in the form of constants in the various cost equations.

FIGURE III - 12

A MULTIVARIATE COST FUNCTION



From the preceding considerations, it is possible to state cost relationships as follows: With respect to short run situations, costs are equated to the sum of the fixed and output variable costs. Here fixed cost would be in form of a constant and the output variable costs would be in form of a coefficient representing the slope of the cost function multiplied by the traffic volume. With respect to the long run, "size costs" are added to the sum of fixed and output variable costs; these are made up of the product of the size variable and the coefficient representing the slope of the statistically fitted function in its cost-size dimension (267, pp. 23-24).

There are essentially three basic approaches in arriving at empirical cost determination: (1) traditional cost accounting; (2) "engineering costing" (this is closely related to cost accounting though more sophisticated than the former); and (3) statistical costing--a relatively new method, based on multiple regression, which attempts to fit the plane in Figure III-12 to a set of points derived from a sample of three-dimensional functions. A cost equation then equates maintenance cost; for instance, with the sum of the fixed (threshold) cost, $\overline{OX}$, and the slope of $\overline{XZ}$ (Figure III-12) as a regression coefficient multiplied by plant size (i. e., amount of facilities and heavy equipment, $\overline{OA}$, plus the slope of $\overline{XY}$, given as a regression coefficient) multiplied by total passenger miles, $\overline{OB}$, plus an error term denoting the distances between various points and the plane.

Statistical costing is most helpful in cases where the establishment of cost-quantity relationships are impossible or difficult.

Before closing this brief review of the more important underlying concepts of cost and production theory as related to transportation, the

concepts of joint-costs and common-costs need to be introduced. Joint-costs arise whenever more than one product (a by-product) is created in a production process. For instance, an east-bound moving way (rail or highway) at the same time creates a capacity for west-bound traffic. It can be said, therefore, that traffic in opposite directions is conducted at joint-costs (141, p. 346; 272, p. 20). Thus, it is a matter of guess-work as to how much of the costs are properly allocated to the east or westbound traffic respectively. This inability of allocating costs other than arbitrarily is best represented by the concept of common costs. Railroads, for instance, provide a number of different services (freight, mail, passenger, etc.) using the same plant and facilities (tracks, station, etc.). The maintenance of tracks and buildings is beneficial both for freight and passenger service; the costs incurred are common to both services and their allocation among the various goods and services is by necessity arbitrary.

Great areas of disagreement exist as to how cost should be allocated and how various costs should be interpreted. The fact that common and joint costs exist, that many of the services of the various transportation media are complementary rather than competitive, and that cost accounting procedures vary widely prevents an entirely satisfactory theoretical analysis of the problem.

## Basic Rate-Making Principle

Pricing is the core problem of any large enterprise and the transportation industry is no different. Two general point of views have evolved with respect to price policy--one emphasizes the necessity of high prices for the maintenance of high earning power; the other view

relies on low prices to provide the stimulus for large volume and thus ensure satisfactory operation.

The two main elements of the rate-making principle are the cost of service ( i. e., costs incurred while producing the service), and the value of service.

Cost of Service. The difficulties arising out of joint and common costs have been mentioned before. It is possible to pro-rate constant costs equally among all ton and passenger miles of traffic and then add them to average variable unit costs; this is called fully distributed costs. Nothing ever moves at fully distributed rates (272, p. 212). The Interstate Commerce Commission found goods moved anywhere between 10% below to 200% above long-run variable costs. The existence of considerable amount of constant costs provides a good motive to vary rates according to the particular characteristics of demand.

In cases where traffic would not move at all unless low rates were charged, it seems justifiable to charge less than total costs as long as "out-of-pocket" variable expenses are covered. The losses here would be offset by gains made on traffic where it would be possible to charge more than the variable cost involved in the service. The basis of this type of reasoning is anchored in the fact that by nature, constant costs will be incurred anyway and the more contribution can be extracted toward overhead costs the better. The practice of differential charging, "discrimination", is defined as those differences in rates which are not attributable to differences in the cost of service (246, p. 134). Some underlying factors in cost differences are (for instance):

(1) Loading characteristics.

(2) Volume of movement.

(3) Regularity of movement.

(4) Services and equipment.

The fact of rate discrimination accounts for such "confusing" phenomena in railroad economics as carrying items at less than full cost and yet making profit at it.

Value of Service. This concept means that something is worth what the customer is willing to pay; i. e., "what the traffic will bear". Value of service is sometimes also defined as the existing price difference in the price of an article in two different places. Thus, if the price of an article X is 30¢ higher at a place A than it is at B, 30¢ would represent the possible upper limits that could be charged for transportation of X from A to B. Because it would not be worthwhile to the seller of X to sell at a loss at B when he could have gotten a higher price at A (demand is assumed as given).

Carriers know that it is not possible to charge fully distributed costs. Thus, with the approval of ICC, they attempt to manipulate their rates in such a way as to equal variable costs, at least (although in some instances they go even below that in order to secure the traffic). The reasoning in such cases is that excess capacity exists which might best be used as contribution toward fixed costs. Some of the following factors form the basic considerations in the value-of-service rating (272, p. 214).

(1) Value of the commodity (the higher its value, the higher rates it should be able to absorb--barring competitive factors).

(2) State of manufacture (finished product) often takes higher rates than applies to raw materials.

(3) Use of a commodity (commodities with different uses, where it is hard to determine the real nature of the commodity).

(4) Industry conditions (the position of the "customer" industry can sometimes affect rates).

Value of service pricing has often been called discriminatory. It has been pointed out, however, that within reason "differential pricing" (a less offensive term denoting that discrimination is within reasonable limits) might be necessary in the transportation industry due to the difficulties inherent in assigning costs exactly to various services or commodities. Distance considerations do not affect value of service, but, of course, they do affect cost of service and thus influence the rates charged.

The above was a brief description of the basic principles underlying fundamental rate theory. The principles just described have been developed originally in connection with railroad rates and primarily were related to freight rates. However, the basic concepts apply to the newer transportation media, and with varying degrees of modifications, form the fundamental set of logic underlying rate theory for the entire transportation industry.

The above theory can also be applied to passenger traffic in the following manner. Cost of service is usually increased in passenger transportation due to factors relating to safety, frequency, comfort, and

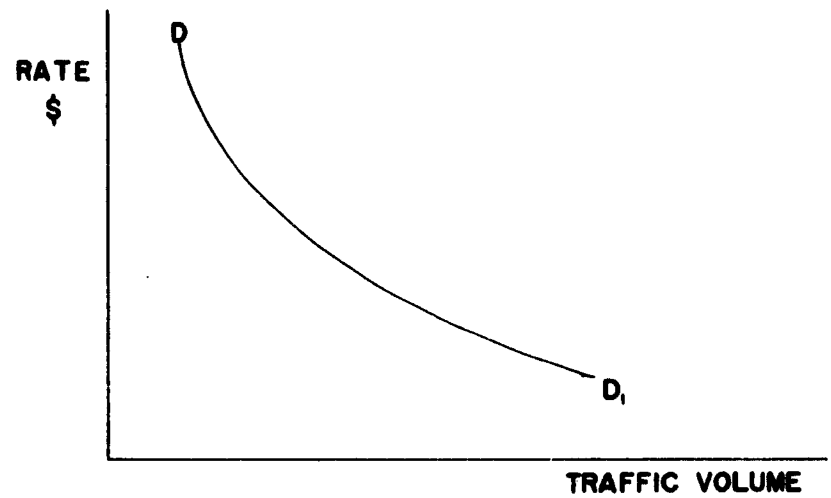
aesthetic aspects of transportation. Air-conditioning, dining facilities, etc., usually result in an increase in the cost of the service. The value of service concept can also be applied to passenger traffic. In Europe, for instance, the railroad provides three classes of service at three different fares. In the United States, pullman and coach service plus a host of special fares (tourist, holiday, etc.) at varying prices point to the existence of differential pricing even in passenger traffic. Rate-making theory, historically, was developed in regard to the railroad industry and it is the only organized, coherent theoretical basis for rate-making in existence. The theory can be applied to other media, but it fits somewhat less well depending upon the particular system under consideration. Also, regulations governing the various airport transportation media must be taken into account in its application.

## Some Demand Characteristics

The pricing system based on the rate-making theory already described is what economists call a demand-oriented pricing system, as opposed to a pricing system related to long-run marginal costs. The latter system usually develops under competition in "unregulated" industries which is not the case with airport transportation media. The cost function and some of its analytic uses have been explained before. It is appropriate, at this point, to consider the demand side of the problem. Demand-oriented pricing has special relevance in an industry where fixed costs are of great importance. Demand-oriented pricing results in better exploitation of capacity and minimization of fixed costs.

Equivalent to the concept of the cost function is the demand function which is another basic analytical tool. The demand function expresses

the relationship between changes in traffic volumes and the variation of rates, assuming the level of economic activity and the nature of the product as given. A simple demand function can be given as follows.




The curve $DD_1$ indicates the so-called law of demand; i. e., the lower the rates, the more of the product is demanded. Different products (in this case the output of airport transportation media) have, of course, different demand curves. The sales response to price changes is expressed by the concept of elasticity of demand. The elasticity of demand is expressed by the ratio of percentage change of quantity demanded over percentage change in price. There are three kinds of demand elasticities:

(1) Elastic demand (increase in price decreases revenue, and vice versa).

(2) Inelastic demand (increase in price increases revenue and vice versa).

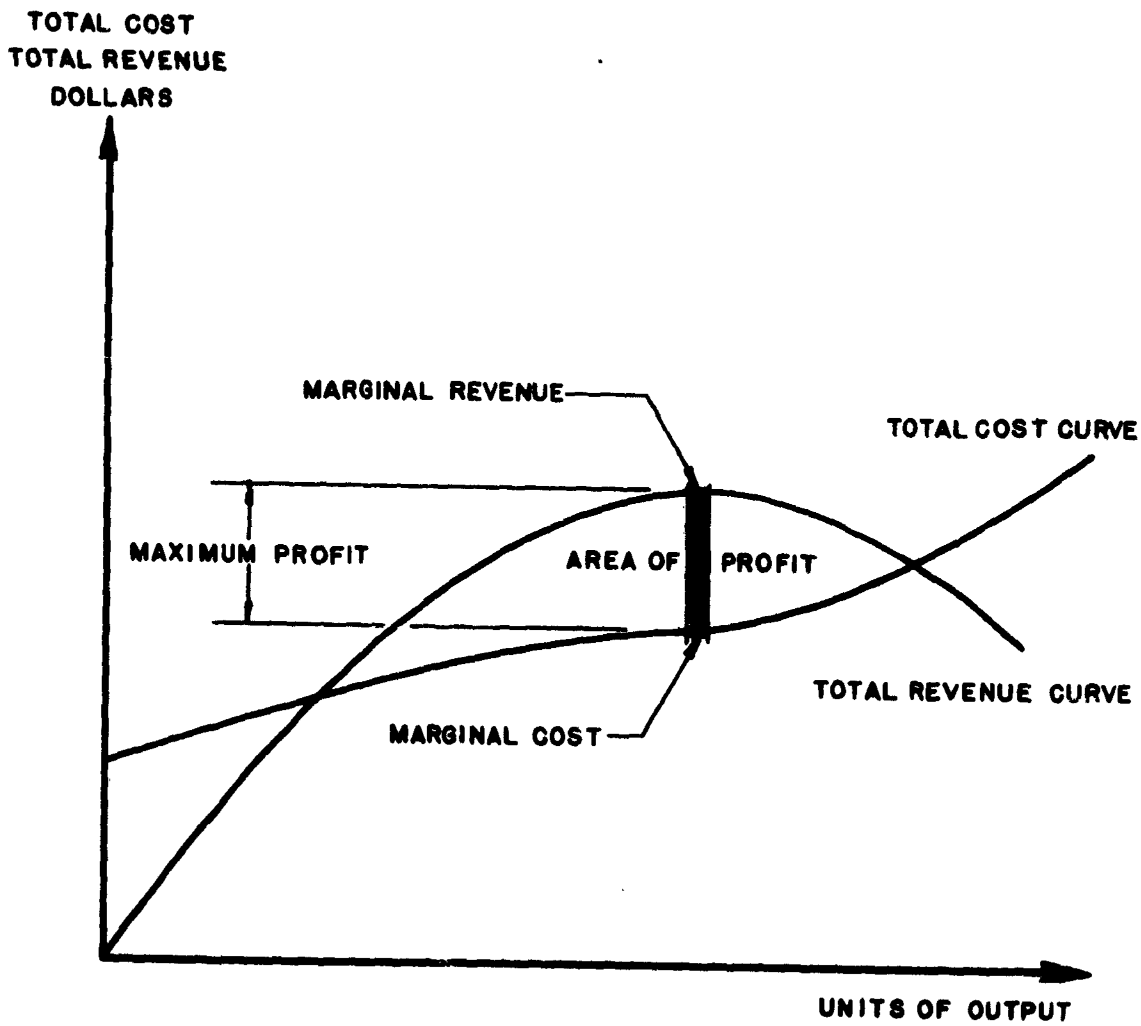
(3) Unit elasticity (changes in price leave revenue unchanged).

The above price changes have to be considered as relatively small price changes. A large enough price change can transform even normally inelastic demand into elastic demand and vice versa. At least one occasion approaching an infinitely inelastic demand situation is known in connection with urban transportation. In Toledo, Ohio, an attempt was made to boost transit demand by means of offering free transit rides anywhere in the downtown area. It was found that there was no substantial increase in the number of passengers carried. The elasticity of demand indicates the changes of total revenue with respect to change in price. The incremental change in revenue is the marginal revenue. The concept of marginal revenue is the equivalent of the marginal cost concept on the demand side. Marginal revenue and marginal cost can be graphically represented by the slopes of total revenue and total cost curves, respectively. It can be shown that profits are maximized where the marginal cost (MC) equals marginal revenue (MR). The relationships between marginal cost and revenue are depicted in Figure III-13. It can be seen that the area of profit is the widest (i. e., profit is the greatest where the slopes of the total revenue curve and total cost curve are equal; therefore, MR = MC). Profit is the vertical distance between the two curves surrounding the area of profit.

The location of the airport with respect to the local origins and destinations of airport users has a decided influence on demand. The pattern of local origins and destinations is not known with any precision or completeness for any city in the United States. From the partial data that are available (see Parts I and II), an argument can be made along the following lines.

FIGURE III - 13

RELATIONSHIP OF REVENUE TO COST



(1) Passengers, visitors, and employees each constitute approximately 1/3 of the daily airport population.

(2) Approximately 40% of the passenger group comes from or goes to the central business district. Probably no more than 3% each of the visitors and employees originate or terminate in the downtown area.

(3) Except in the central business district, origins and destinations are distributed thinly and widely over the entire metropolitan area.

If the above are true--which the available evidence indicates--then, as a general pattern, about 15% of the local origins and destinations of the total daily airport user population are concentrated in the downtown area and the remainder are widely dispersed over areas of the magnitude of 200 to 400 square miles.

Thus, the popular notion of "airport to city center being the major travel route" needs to be carefully examined. In general, the volume of traffic generated by airports is not so large as would readily justify entirely separate transportation.

The above comprise some of the factors which have to be taken into account in attempting to discern the demand function of airport transportation.

## Delineation of Economic Factors of Airport Transportation

Figure III-14 has been developed as a schematic representation of economic factors related to airport transportation. It is intended to serve as a visual aid to accompany the following explanations. The

schematic gives a rough idea of the relationships among the various factors. Its sole purpose is to furnish an illustrative aid to the text.[1]

The schematic consists of a set of blocks connected by arrows. The lists in each block serve, in most cases, as indicators of the economic factors (ideas, concepts and things) represented by the title of the blocks. These lists are not exhaustive. The arrows denote relationships that will be discussed in the text. Double arrows denote a reversible type of relationship, with factor A both influencing and, at the same time, being influenced by factor B. This type of relationship in reality exists among and between all the factors; however, only those two-way interactions are shown which were judged as being of key importance to the airport transportation problem. The text is organized in accordance with the number assigned to each block.

### 1. Airport Transportation Systems

This block merely names the means by which airport transportation is or can be accomplished. At all airports, a mix of several systems exists and this will probably be true in the future, although new developments will undoubtedly subtract or add systems to the mix and change the proportion of traffic carried by each. An airport transportation system consists of the facilities, the way, and the vehicle. A more complete break-down by way and vehicle system is as follows.

(1) Highway

a. Private automobile
b. Taxi
c. Bus
d. New concepts

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[1] Figure III-14 is printed on a fold-out page (following page 212). The reader may fold it out to have in view while reading this section.

(2) Rail

a. Subway
b. Railroad
c. Streetcar
d. Monorail
e. New concepts

(3) Air

a. Helicopter
b. V/STOL
c. New concepts

(4) New ways

The arrow leading to the second block denotes the fact that all systems operate by employing the factors of production.

2. Factors of Production

These are four in number, as used traditionally in economics:

(1) Land

(2) Labor

(3) Capital

(4) Management

Land as a productive factor in economics means both land in its literal sense, and it is also taken to mean natural resources. Labor and management comprise the human element in the various systems. Capital, in an economic sense, stands for plant and equipment and also investible funds.

The arrow leading to the third block shows that it is the prices of (rewards paid to...) the factors of production which make up the costs incurred by the various systems. Thus, the quantity and quality of the factors of production are of prime importance as cost determinants.

### 3. Costs

The term "cost" has a number of different meanings, depending on who interprets it, for what purpose, and under what conditions. There are many cost concepts in use. Those most relevant to the present problem are listed in the diagram. There are several obstacles to being specific about costs. Among these are the following.

(a) Differences in basic philosophy and viewpoint with respect to costs by various disciplines.

(b) Varying interpretations of costs by different groups.

(c) Difficulty in selecting the proper framework for a logical classification system for cost concepts, because different cost combinations are appropriate to different problems, and because cost concepts differ qualitatively among themselves.

There is a basic disagreement between economics and accounting concerning economic reality.[1] The basis of the controversy is the difference in perspective along the time continuum from which reality is viewed.

For the economist, the basic source of value of today's assets lies in the future. He sees what happened in the past as irrelevant; historical data are only useful as forecasters of the future. Thus, it is future expectations, according to the economist, which should influence present decisions. Bygones are bygones; and once a finished good has been produced, its cost becomes irrelevant with respect to sales price or profit. Should current market price fall, it is more than likely that the businessman would sell at a loss (i. e., below full costs) within certain limits,

[1] Much of this discussion is based on reference (449).

depending on the product, rather than risk further losses if he <u>expects</u> prices to fall even further. It is the businessman's <u>future expectations</u> concerning his market which determines the prices he is willing to pay to the productive factors today in producing a certain good. Furthermore, the economist contends that cost is a relative matter. Items which are to be looked at as costs under one set of circumstances might not be costs under different conditions. What is cost, according to the economist, in the final analysis depends on the nature of sacrifices produced by a particular business decision. What and when to include or exclude as cost in a business venture is another area of disagreement. Thus, the balance sheet of the economist attempts to aggregate the future earning of a firm's assets, with each asset having its own earning power, depending on whether the organization is a "going concern" or not, and whether or not it is able to command goodwill (<u>i. e.</u>, if it is established with good reputation or not in its market).

The accountant, on the other hand, for the sake of "factuality", has as his main interest, by the nature of his task, the reporting of historical facts; <u>i. e.</u>, costs incurred in past transactions. He is little, if at all, receptive to suggestions of speculating about the future and is equally unenthusiastic about giving too much thought to how to measure goodwill (though his balance sheet occasionally does contain some intangible items of this nature; <u>e. g.</u>, patent protection, which, in a way, is anticipation for the future). Furthermore, the accountant is unhappy with the economist on the basis of "difficulties" of "accurately" measuring today--in dollar terms--values of assets on the basis of future expectations materializing. The accountant measures income by determining the difference between net assets at the beginning and at the end

of the year. Financial accounting has as its main task the determination of the over-all asset status and the origin and disposition of funds in a given period of time. Thus, the accountant needs standard and unchanging definitions of cost; and the idea of a given item being considered as cost under some circumstances and not as cost under others becomes untenable. Finally, the meaning of depreciation costs is a source of disagreement. The accountant, by relating depreciation reserve to original rather than replacement costs, limits the usefulness of depreciation accounting to the most basic hypothetical conditions of stable prices and foreseeable obsolescence.

The conflict between the two professions was the most heated during the inflationary years of 1941-1948. The question now arises, "who is right?" There is no simple, unequivocal answer to this question. Probably the best answer is the one which does not really answer the question as stated, but which says that both viewpoints are useful and needed as long as one realizes the limitations of the other's position and his own realm of competence.

Accounting is competent in special aspects of financial analysis and for the codification of public regulation and tax administration. Due to the importance of legal consequences of accounting, great uniformity of method is required. On the other hand, most business decisions require the type of analyses advocated by the economists. The basic difference between the two standpoints should be understood. The tangible nature of accounting procedures and cost concepts involved (i. e., routinely recorded past transactions in dollar terms) lends them a special aura of reality and exactness which may explain the wide-spread belief that financial accounting costs are relevant to all types of business

decisions and that the economists' approach is "academic" and not realistic. Finally, the limitation of the economic approach--that it is unable to come up with "neat and exact" quantitative measurements for its own balance sheet and can only make general profit estimates--further contributes to the predominance of accounting procedures as the basis of many business decisions. Fortunately, there seems to be more and more recognition of the special areas of competence of accounting and economics and greater realization of the degree to which they can make use of each other's knowledge.

Neither discipline can, however, now escape the essentially arbitrary aspect of some of their cost allocation procedures. Realizing the nature of the basic conflict in the thinking of the two disciplines which supposedly are the most concerned with the "cost" of things in a scientific (or in the case of accounting, in a consistent manner) fashion, it becomes inreasingly clear what some of the inherent difficulties are in describing a set of cost concepts. Not only has each discipline evolved its own set of concepts, but in addition sometimes re-christened the same general concept with different names.

As an illustration, the concepts of traceable costs and of common costs show some of the confusion in this respect. A traceable cost can be defined as one which can be easily allocated; i. e., traced to a product. In accounting terminology, direct and indirect costs are distinguished on the basis of traceability. Direct cost = traceable costs and indirect cost = non-traceable costs.

In economic theory, on the other hand, these concepts are replaced by separable cost (traceable) and common cost (non-traceable) with common cost breaking down into joint-product costs and alternative

product costs, depending whether an increase in the output of one product does or does not increase the output of the other product (for instance, if an increase in ham at the same time increases the output of pork shoulders, the two have joint product costs and their costs are not traceable; i. e., it is common cost. If an increase in the output of ham drives down the output of pork shoulder, they have alternative product costs).

Economists and accountants are not the only users and interpreters of cost concepts, however. Engineers and statisticians also have their own cost interpretations. The complexity of the situation is further increased by the fact that cost concepts differ qualitatively among themselves. For instance, variable costs can be joint or common, and vice versa, but opportunity costs are usually not thought of as being joint or common. Incremental costs are taken by some as being the same as marginal costs. Others interpret them as being different from marginal cost in so far that marginal cost is considered as the increment to total cost when an extra input unit is added, but incremental cost is that increment to total cost when there is a change in the level or the nature of the activity. Finally, different cost combinations are needed for different kinds of problems; this and qualitative differences make a logical classification framework very difficult.

Returning to the explanation of the schematic diagram, it is quite obvious that the concepts listed do not furnish an exhaustive or unique list.

The cost concepts listed are the following.

(a) Fixed costs.

(b) Variable costs.

(c) Opportunity costs.

(d) Out-of-pocket costs.

(e) Common costs.

(f) Joint costs.

(g) Outlay costs.

(h) Short-run costs.

(i) Long-run costs.

All of these costs have been explained previously except three which will be briefly defined here.

The concept of opportunity cost is used in economics and denotes the alternatives foregone by choosing a certain course of action; the alternative foregone is the cost of the alternative chosen. A more precise definition reads as follows: Opportunity cost is a cost (money or imputed) which is measured by the income (or price) a productive agent could receive in its best alternative employment.

Outlay costs are those costs which involve financial expenditure and which are recorded in the books of account. Opportunity costs are never recorded as such in the books of account.

Out-of-pocket costs are those costs which require current cash payments to outsiders. In one of the transportation studies, it was found that the size of the out-of-pocket costs were the most important determinants of the transportation mode a person is likely to choose (273, p. 40).

The arrow leaving block three and entering block four denotes the fact that the amount of systems cost will be a major determinant of airport transportation supply. This could also be stated as saying that the factors of production through costs participate in determining the quantity and quality of the transportation supply by a given system.

4. Supply

Supply can best be expressed in some form of output unit. In this case it is either:

(a) Passenger miles

(b) Seat miles

(c) Ton miles.

Any one of the above three could be used to measure airport transportation supply. Two of the three output concepts have been defined before and the third one (that is, seat mile) is defined essentially the same way as the other two with the exception that space replaces the passenger and the one ton weight in the other definitions.

This completes the supply side of the picture with respect to direct relationships. The next step is now to start reading the schematic along the demand side in block five.

5. Airport Users

These are people who actually use the airport. This group of people is comprised of four sub-groups as defined earlier in the text, consisting of:

(1) Passengers

(2) Employees

(3) Visitors

(4) Service suppliers

The arrow leaving block five and entering block six indicates that airport users use the airport for different purposes.

### 6. Trip Purpose to Airport

Airport users travel between the airport and other points for a number of reasons, among which are:

(1) Passengers

a. business trips
b. pleasure trips
c. personal emergency
d. school
e. change of residence
f. military travel

(2) Visitors

a. accompany passengers
b. use airport concessions
c. sightseeing

(3) Employees--place of work

(4) Service suppliers--to perform services

The arrow entering block seven from block six represents the idea that people, traveling for given reasons to and from the airport, create airport transportation demand.

### 7. Demand

Airport transportation demand can be defined as a combination of the number of people who want to travel to and from the airport and the price they are willing to pay for it.

Airport transportation demand is generated essentially by the following groups of travelers who were defined in Part I:

a. Passengers

b. Employees

c. Visitors

d. Service suppliers

Some conjecture as to the nature of the demand generated by these four groups can be ventured.

a. Passengers. This group consists of business and pleasure (or personal) travelers. Convenience and speed are the most important determining factors of the demand characteristics of those who travel for business reasons. They often travel on expense accounts and their own time is itself of value to their employer. Thus travel expenses probably are of less importance than with other classes of passengers. With respect to the pleasure travelers, it can be argued that since the expense of airport transportation is such a small fraction of the total cost of their trip and since traveling for pleasure is a luxury in itself, such expense is probably not given major consideration within reasonable limits (182, p. 6-8).

The above carries the implication that speed and convenient scheduling are far more important than the size of the fare, within limits, charged by airport transportation media. This view gets added impetus if one considers the fact that air travel--being one of the most expensive ways of travel--has tended to attract customers from the higher income group, although recent market surveys give evidence that the income spectrum of air travelers is becoming broader.

b. Employees. The people in this group work in one or another capacity at the airport. In contrast to the other groups, this

group can be considered as being more conscious of the expense involved in getting to and from the airport.

c. Visitors. This group consists of those accompanying or meeting passengers, of sightseers, and of users of airport concessions. Here again, a case can be made on the grounds mentioned above with respect to those who are accompanying or meeting passengers that time is as important to them as it is to the passenger they accompany. It is more difficult to venture a guess concerning the true sightseers as to the importance they attach to monetary considerations.

d. Service suppliers. This group includes people who make deliveries or provide services at the airport. Normally they will use special purpose vehicles and are, therefore, not of concern in this study.

The relative importance of the first three groups from the point of view of total airport transportation demand is approximately equal, in terms of the volume of airport traffic they constitute. The proportion of each group varies considerably from airport to airport.

At this point, we have completed the supply side and the demand side of the schematic. The next step is to consider block eight, Metropolitan Transportation Problems.

## 8. Metropolitan Transportation Problems

Included here are factors which influence urban transportation. They represent, for the most part, obstacles or problem areas which transportation must contend with or overcome. Included are:

a. Population increase

b. Space decrease

c. Terrain features

d. Structures (street system, etc.)

e. Congestion

Many of the factors are contributors to traffic congestion. As the congestion increases, travel time slows, increasing travelers' frustrations--which tends to bring with it increased intensity of the desire to reach their destination. The increased intensity of desire is manifested by a willingness to pay more for transportation. Thus, congestion affects demand.

Congestion, on the other hand, lessens supply essentially by decreasing the number of available passenger miles in a given time period. As congestion slows traffic, it means, for example, that a taxi can make fewer trips to the airport for any given time interval. Thus, both supply and demand are affected.

Airport transportation is inextricably bound up in general metropolitan transportation and can not be meaningfully considered apart from it. Not only are supply and demand affected by their environment (metropolitan transportation problems), but they, themselves, take part in the shaping of that environment.

### 9. The Price Mechanism

Supply and demand through the price mechanism determine the final systems output. The price mechanism in turn--by standing between production and consumption--equates demand and supply. Supply and demand act on each other through the price mechanism and thus determine how much is actually consumed.

Supply and demand together determine fares, subsidies, taxes, etc. and through these the financing of the transportation system is accomplished. The type and amount of the financing (how much comes through revenues from fares or from subsidies or from taxes, or what type and how large a bond issue, or what form the subsidy takes, etc.) is of great importance and determines the financial health of the system which, in turn, largely determines the quality and quantity of transportation output. At the same time, however, the price mechanism also affects supply and demand. On the supply side, the influence of price means that the amount of revenue will determine the amount of transportation supplied. If fares are high and cover costs, or if generous subsidies are given to make up for losses, the transportation industry will (will be able to) supply any amount of transportation required. On the demand side, the influence of price means that the amount of transportation purchased will depend on its price.

Demand and supply act on each other through the price mechanism, which is the equilibrating force. This interaction can be described as follows: If the price is high, demand will fall off, causing revenue to fall off also. In the beginning, there will be an excess supply of transportation which will have to operate at lower prices in order to attract trade. This fall in price, however, will sooner or later cause supply to shrink. As the transportation supply keeps decreasing, more and more people will find it difficult to travel. Excess demand will now appear and the public will again be willing to pay more for transportation, be it through fares or subsidies. Thus, prices will rise again and supply will expand in a renewed attempt to equate itself with demand, and the cycle might start anew.

Price, in this context, is not taken to mean a well-defined market price but rather the total financial outlay of the community (both public and individual expenditures) for its transportation.

10. Output

Output has essentially the same meaning as supply in block four, with two important exceptions. First of all, whereas under supply the available capabilities (given in passenger or seat or ton miles) of the various systems were meant, only actual service sold out of the available service is considered as output. This means the load factor, that is, how many passengers were actually carried divided by the maximum number that could have been carried, and not just how many could have been carried. The second main difference is that output includes time utility as its most important component, whereas supply per se does not.

While it is impossible to measure utility per se, it is possible to assign a monetary value to time, which--in a sense--can be taken as an indirect reflection of the value of time utility. The value of time can be calculated from income, as will be discussed later. Two systems can be compared with respect to the total trip time between any two points and the time difference expressed as a monetary value.

The time savings produced by one system vis-a-vis another system is considered as an output of the system. More conventionally, the output of the system can be conceived of as a service to the customer. The service purchased by the customer consists of transportation between two points which consumes some interval of time. The value of the service can be expressed as a combination of the fare paid and the time spent.

11. Regulatory Factors

The regulatory factors represent the exogeneous variables in the system; that is, they are given from outside of the system and are not determined by it. In a sense, they are part of the environment of the system. Transportation is one of the regulated industries and operates within, and is limited by, the laws and regulations of the federal, state, and local governments. This means that essentially economic considerations are decided on a political level. It is the laws and regulations of transportation which set a definite limit to the area in which purely economic considerations are determining factors. In the schematic, this should be considered as being connected with every other block.

## Economic Parameters[1] for Comparative Evaluation

Our purpose has been to seek means of comparing systems on meaningful and generic parameters. From an evaluation standpoint, there are at least three different reference points that could be taken: the system owner, the system user, and the community. Each of these reference points has somewhat different, although not necessarily conflicting, desiderata. From an over-all evaluation standpoint, it is desirable that parameters be used which reflect these different desiderata. Our analysis of economic considerations has convinced us of the general disutility and inappropriateness of the more traditional cost accounting approaches to system evaluation for our purposes. Instead

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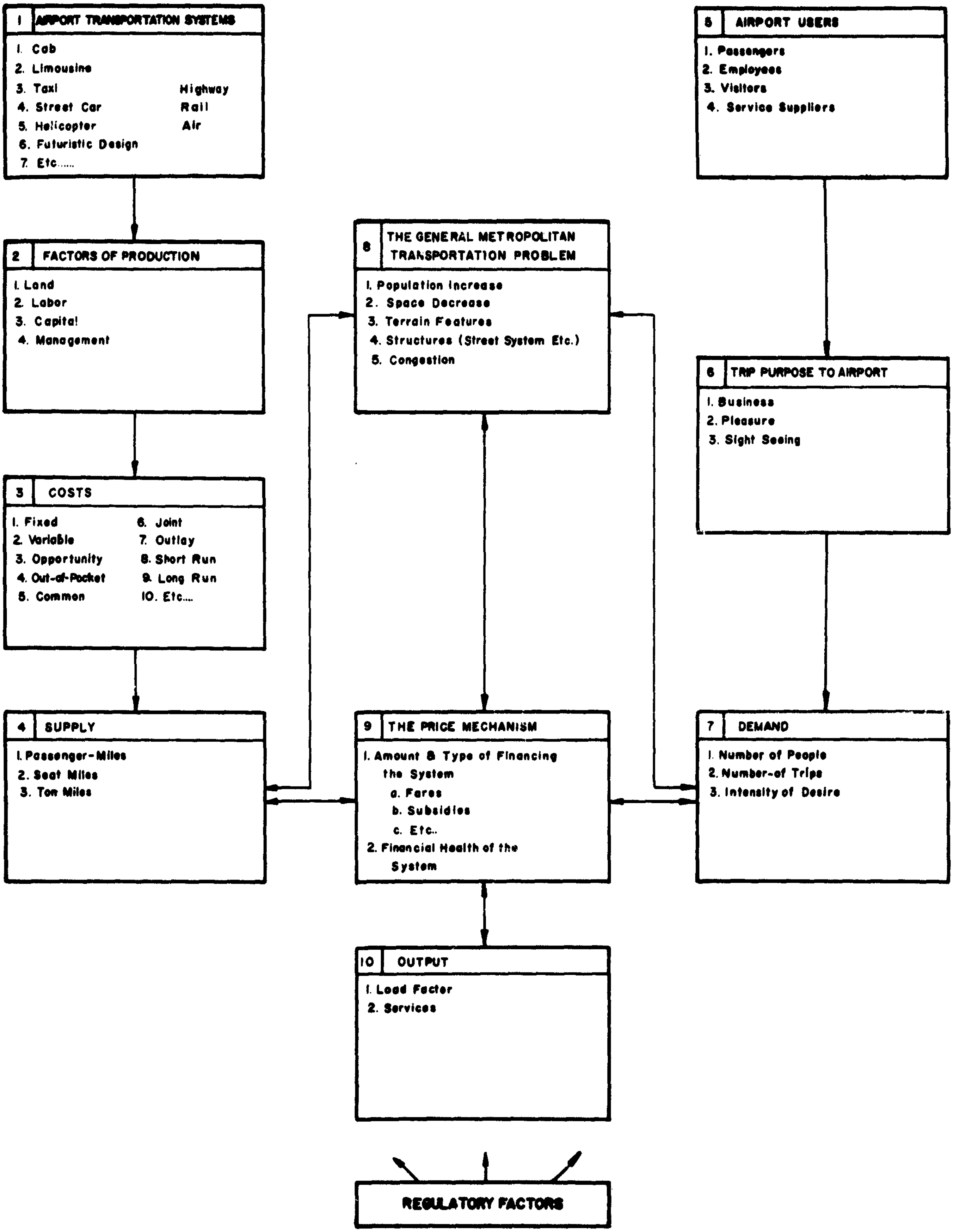
[1] Parameter is used here as defined on page 136, and not in the sense usually meant in economics.

FIGURE III-14

# SCHEMATIC REPRESENTATION OF ECONOMIC FACTORS RELEVANT TO AIRPORT TRANSPORTATION



of trying to develop cost parameters, we have tried to take a somewhat different approach based on the concept of time utility.[1] This approach is developed in the following section. As a new approach, all of the possible implications of its use have not been worked out, but it appears to offer sufficient promise to warrant further consideration. Among the advantages it offers is that information is provided which is interpretable from all three reference points.

It should be understood that the approach we are taking does not pretend to resolve all of the many questions that can be posed from an economics standpoint. Rather, it offers one means of structuring a number of economic considerations we believe to be pertinent to the present research task.

It has been shown that cost comparisons can provide very little useful information from an evaluative standpoint. This does not mean, of course, that cost accounting methods and other cost information are not useful to the system owner or operator and the public. Clearly they are, and they must be taken into account when decisions are made. However, from an objective standpoint where the question is one of establishing comparative facts among different systems, cost information as it is presently determined is so subject to multiple interpretation that it does not serve the function of the kind of evaluative parameters we are seeking.

For these reasons, we have tried to devise a means of comparing systems on economic criteria which would perform at least some of the

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[1] The approach is similar, in part, to one used by Williams in comparing helicopter and limousine service (436).

functions desired. What is described in the following pages is essentially a method of determining relative price paid by the consumer for the services of any two systems. Prices are arrived at by adding fare and the value of the time difference expressed in monetary terms. The relationships between the prices of any pair of systems can then be examined.

Essentially, the method provides a comparison between systems in terms of the value of the service produced; this value is composed of fare plus the value of trip time. As different values of time are considered, the results of the method reflect the changing relationships between systems which are produced.

Assumptions:

(1) Air travel is used because it creates more time utility for the user than any competitive travel mode.

(2) Any air trip requires airport transportation and, therefore, airport transportation is a partial contributor to the time utility created by air travel.

(3) It is appropriate, therefore, to compare airport transportation systems in terms of the time utility they contribute to the total trip.

(4) The value of time can be determined from income inasmuch as income is the only expression of the value of an individual's time in our economy.

(5) For any airport, the local origins and destinations of airport users can be determined.

(6) For any airport transportation system, the following empirical facts can be established (measured or estimated): fare (price), and trip time between any two points identified in (5).

Method. The method will be explained by using an example in which limousines, taxis, and helicopters are compared on a single hypothetical run. Using computers, all--or a random sample of all--possible runs can be calculated and the systems could then be compared on their ability to move the total volume or any part of it which is of interest. For the purpose of exposition, however, only one run will be used. The method is most easily described by showing the steps by which the index is calculated.

1. Obtain basic data. Establish the two points being considered, the fare between them for each mode, and the trip time for each mode. This example will examine the trip from Midway Airport to Chicago to the intersection of State and Madison in the Loop by three different modes.[1]

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[1] Limousine and taxi data correspond to actual values at the present time. At present, the closest heliport is at Meigs Field, about five minutes taxi time from the Loop. For this example, it is assumed that a heliport is located in the Loop (which it would be if the plan described in the chapter on Chicago is carried out). Thus, to simplify the example, all modes are assumed to connect the same two points directly.

Trip time is defined as travel time plus waiting time. Travel time is the time interval between the time the vehicle leaves its originating point and the time it reaches its destination point. Waiting time is the time the passenger must wait at the originating point before the vehicle leaves. In this example, it is assumed that there is no waiting for taxi, 10-minute waiting time for limousine, and 8-minute waiting time for helicopter. Waiting time at the originating point is taken as 1/2 headway; waiting time can also occur at intermediate stops. Thus, a 16-minute headway is assumed for the helicopter which is a considerable improvement over the present 36-minute median headway between Midway and Meigs Field.

| Mode | Trip Time (minutes) | Fare |
|---|---|---|
| Limousine (airport bus) | 45 | $1.45 |
| Taxi | 35 | $3.50 |
| Helicopter | 15 | $5.00 |

2. Determine the value of time. In our society, the only valuation placed on a person's time is the income he receives divided by the time he spends earning it; that is, working time. It is appropriate, therefore, to assign a money value to time equivalent to the only valuation of time that exists. Obviously, the value of a person's time varies as his salary. Initially, however, we will take an average or population value for time although certain refinements will be introduced later.

The value of time was calculated by taking the national income figure and dividing it by the number of people in the labor force which resulted in an annual salary of about $6,167 per earner. Dividing by the number of minutes in the normal working year, the monetary value of time in the economy is determined. One minute is equal to $0.0494.

3. Obtain comparative time and fare differences between modes. Comparing each mode with each other mode in terms of trip time and fare, the following differences result.

| | Fare Difference | Time Difference (minutes) |
|---|---|---|
| Limousine vs. taxi | $2.05 | 10 |
| Limousine vs. helicopter | $3.55 | 30 |
| Taxi vs. helicopter | $1.50 | 20 |

These figures show the differences that result in fare and time when one mode is chosen instead of another. Depending on which of the two modes in any pair is chosen, the differences listed above can be considered either as saved or additionally spent by the customer. Since we have a money value for time, it becomes possible to convert time saved or additionally spent into dollar values and combine time and fare differences into a single value.

4. Obtain fares and times for services of equal value. From the above differences it is possible to compare each mode with each other mode and calculate the fare each should charge in order to provide a service equal in value to the service provided by the mode to which it is compared at present fare and trip time. Thus, comparing the limousine against the taxi, the following results.

| | | |
|---|---|---|
| Taxi fare | | \$3.50 |
| Value of time saved (if taxi were taken) | − 10 minutes x .0494 | − .49 |
| Limousine fare for service equal in value to taxi: | | \$3.01 |

Conversely, by comparing taxi against the limousine, the following is obtained.

| | | |
|---|---|---|
| Limousine fare | | \$1.45 |
| Value of time added (if limousine were taken) | + 10 minutes x .0494 | +.49 |
| Taxi fare for service equal in value to limousine: | | \$1.94 |

Carrying out the above procedure for all comparisons, the following table is generated.

**Fares for Services of Equal Value**

| Fare for: | Expressed in Terms of: Limousine | Taxi | Helicopter |
|---|---|---|---|
| Limousine | X | $3.01 | $3.52 |
| Taxi | $1.94 | X | $4.01 |
| Helicopter | $2.93 | $4.49 | X |

The mode on the left of the table should charge the fare indicated under the mode on top for it to provide a service equal to the value, at its present time and fare, of the mode at the top. Thus, the limousine fare, $3.01, in the taxi column means that if the limousine charged $3.01 instead of $1.45 it would provide a service equivalent to that provided by the taxi. Conversely, the taxi would need to reduce its fare from $3.50 to $1.94 for it to provide an equivalent service to the limousine.

The above fares assumed that trip times remained unchanged. However, it is also possible for trip time to be changed to produce a service of equivalent value. A procedure analogous to the one explained for fare is followed to determine the trip time which the mode on the left should achieve for it to provide a service of equivalent value to the mode on top--assuming fares remain unchanged. Using this procedure, the following times are generated.

Trip Times for Services of Equal Value

(Minutes)

| Trip Time for: | Expressed in Terms of: Limousine | Taxi | Helicopter |
|---|---|---|---|
| Limousine | X | 76 | 87 |
| Taxi | 4 | X | 45 |
| Helicopter | -27 | 5 | X |

Parallel with the interpretation of the fares in the previous table, the trip times above mean, for example, that the limousine should increase its trip time to provide a service of equal value to the taxi, and the taxi must decrease its trip time in comparison with the limousine.

One caution may be appropriate at this point. The terms service and value refer only to monetary value and time measured in minutes. Service, in the present usage, does not include such factors as convenience and comfort. When we say that the fare or the trip time should be some amount to provide an equivalent value, we mean only that the fare plus the value of the time difference will be equal. Nothing further is implied.

5. Determine comparative time and fare indices. We are now in a position to express the differences between any two modes in terms of the changes required either in fares or in trip times in order for an equivalent value of service to be produced. Tables III-3 and III-4 show these differences between the fares and trip times calculated above and the original fares and trip times.

TABLE III-3

Changes in Existing Fares
Required to Produce Services of Equal Value

| Changes Required in: | To Provide a Value Equivalent to: Limousine | Taxi | Helicopter |
|---|---|---|---|
| Limousine | X | $1.56 | $2.07 |
| Taxi | --$1.56 | X | .51 |
| Helicopter | —$2.07 | —.51 | X |

TABLE III-4

Changes in Existing Trip Times
Required to Produce Services of Equal Value

| Changes Required in: | To Provide a Value Equivalent to: Limousine | Taxi | Helicopter |
|---|---|---|---|
| Limousine | X | 31 | 42 |
| Taxi | −31 | X | 10 |
| Helicopter | −42 | −10 | X |

6. Determining the effect of different values of time. Mentioned previously was the fact that all the foregoing calculations have used a single monetary value for the value of time. Essentially, this was a mean value of time in the economy. However, there is every reason to believe that the part of the population who travels by air is not representative of the general population--particularly in income. The average income of the air-traveling population is higher than the average income of the general population. The value of time to this part of the population is, therefore, higher than the value we have used heretofore.

There is no requirement that airport transportation systems be evaluated against some common denominator. Unquestionably, there is the likelihood that different systems perform somewhat different functions and serve somewhat different segments of the population. We want to have evaluative parameters which permit us to take such differences into account.

In the economic realm, the comparative indices just described provide that opportunity. By assuming different values for time, the indices can be re-calculated and the effect on the relationships between systems of different values for time examined. This procedure enables the determination of the relative value of systems from the standpoint of users having different incomes.

The values of time for people with the following incomes were calculated and are given in Table III-5.

The comparative fare indices were determined in the same way as described above and sets of fare changes (required to produce equivalent values) were produced, one set for each different value of time. These are presented in Table III-5.

## TABLE III-5

Changes in Existing Fares Required to Produce Services of Equal Value
(in dollars)

| Change of fare in → | Limo | Limo | Taxi | Taxi | Heli | Heli | | |
|---|---|---|---|---|---|---|---|---|
| to produce a service of equivalent value to → | Taxi | Heli | Limo | Heli | Limo | Taxi | Monetary Value of Time per One Minute | Annual Income Equivalent |
| | 1.57 | 2.11 | −1.57 | .54 | −2.11 | −.54 | $.048 | $ 6,000.00 |
| | 1.49 | 1.87 | −1.49 | .38 | −1.87 | −.38 | .056 | 7,000.00 |
| | 1.41 | 1.63 | −1.41 | .22 | −1.63 | −.22 | .064 | 8,000.00 |
| | 1.33 | 1.39 | −1.33 | .06 | −1.39 | −.06 | .072 | 9,000.00 |
| | 1.25 | 1.15 | −1.25 | −.10 | −1.15 | .10 | .080 | 10,000.00 |
| | 1.17 | .91 | −1.17 | −.26 | −.91 | .26 | .088 | 11,000.00 |
| | 1.09 | .66 | −1.09 | −.42 | −.66 | .42 | .096 | 12,000.00 |
| | 1.01 | .42 | −1.01 | −.58 | −.42 | .58 | .104 | 13,000.00 |
| | .93 | .18 | −.93 | −.74 | −.18 | .74 | .112 | 14,000.00 |
| | .85 | −.06 | −.85 | −.90 | .06 | .90 | .120 | 15,000.00 |
| | .77 | −.30 | −.77 | −1.06 | .30 | 1.06 | .128 | 16,000.00 |

The same process was repeated for trip times and the results are presented in Table III-6.

The fare changes were computed assuming trip times remained unchanged; the trip time changes were calculated assuming fares remained unchanged.

In order to facilitate visual inspection of the results presented in Table III-5, the results have been graphed in Figure III-15. The 6 columns in Table III-5 are really 3 sets of converse pairs, each member of the pair differing from the other only in sign. Only three lines, therefore, are drawn in Figure III-15. They can be read as follows. The value of the fare change required of the helicopter to provide a service equivalent to the limousine, for example, for any salary range is read from the ordinate value on the left-hand side of the figure. The converse fare change required of the limousine, etc., is read from the ordinate on the right. Thus, for the $10,000 income range, the helicopter fare change to compare with limousine is −$1.15 and the converse limousine fare change is +$1.15. The rule is: to find the fare change for the left-hand member of the pair, read from the left-hand ordinate. For the fare change of the right-hand member of the pair, read from the right-hand ordinate.

The same kind of presentation could be made for trip times, but for present purposes the fare changes only will be discussed.

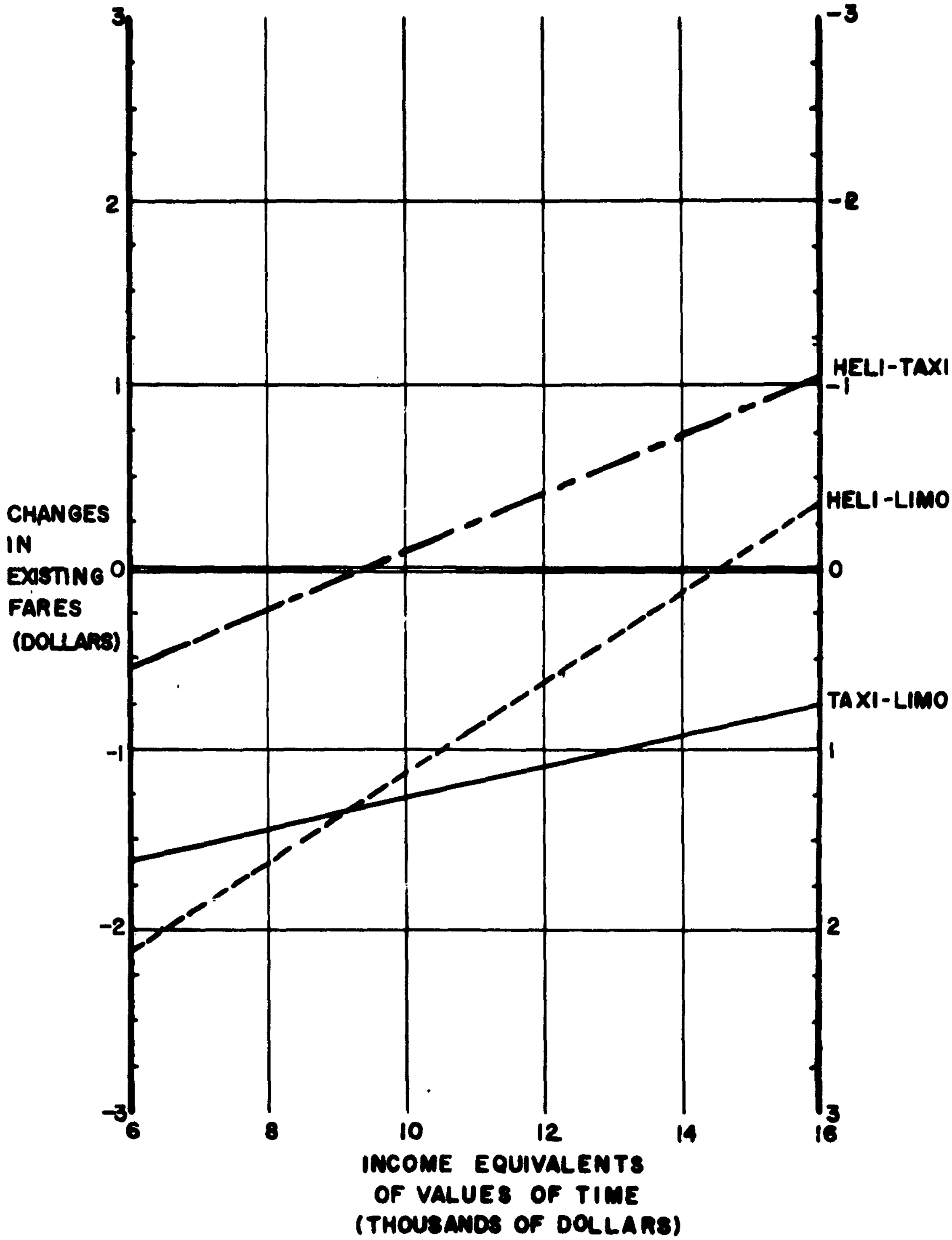
Several kinds of implications can be drawn from Figure III-15. Although it is an example calculated on one run only--and, therefore, not suitable as a basis for general conclusions--the results of a similar analysis for a total set of runs can be presented in the same way. Examples of the kinds of conclusions that can be drawr are as follows.

## TABLE III-6

**Changes in Existing Trip Time Required to Produce Services of Equal Value**
(in minutes)

| Change of trip time in to produce a service of equivalent value to | Limo<br>Taxi | Limo<br>Heli | Taxi<br>Limo | Taxi<br>Heli | Heli<br>Limo | Heli<br>Taxi | Monetary Value of Time per One Minute | Annual Income Equivalent |
|---|---|---|---|---|---|---|---|---|
| | 33 | 44 | −33 | 11 | −44 | −11 | $.048 | $ 6,000.00 |
| | 27 | 33 | −27 | 7 | −33 | −7 | .056 | 7,000.00 |
| | 22 | 29 | −22 | 3 | −29 | −3 | .064 | 8,000.00 |
| | 18 | 19 | −18 | 1 | −19 | −1 | .072 | 9,000.00 |
| | 16 | 14 | −16 | −1 | −14 | 1 | .080 | 10,000.00 |
| | 13 | 10 | −13 | −3 | −10 | 3 | .088 | 11,000.00 |
| | 11 | 7 | −11 | −4 | −7 | 4 | .096 | 12,000.00 |
| | 10 | 4 | −10 | −6 | −4 | 6 | .104 | 13,000.00 |
| | 8 | 2 | −8 | −7 | −2 | 7 | .112 | 14,000.00 |
| | 7 | 0 | −7 | −8 | 0 | 8 | .120 | 15,000.00 |
| | 6 | −2 | −6 | −8 | 2 | 8 | .128 | 16,000.00 |

FIGURE III -15
CHANGES IN EXISTING FARES REQUIRED TO PRODUCE SERVICES OF EQUAL VALUE



(1) In the $6,000-$14,000 income range, the limousine provides a service of the same value at less fare than either helicopter or taxi. Above the $14,000 range, the fare-value discrepancy is in favor of, and greatest for, the helicopter.

(2) The limousine produces the same service for less fare than the taxi throughout the entire salary range. The discrepancy narrows in the higher ranges and would probably disappear at about $18,000.

(3) In the salary ranges up to about $9,000, the taxi surpasses the helicopter. Thereafter, the helicopter produces a service of the same value at less fare.

(4) The taxi is never ahead of both helicopter and limousine at the same time. It surpasses the helicopter in the low salary ranges, but never exceeds the limousine.

The above are merely kinds of conclusions that can be drawn from the use of the method suggested. It needs to be reiterated that only fare and trip time have entered into the above comparisons. For that reason, the fare on trip time changes required for services of equal value can not be taken as prescriptions for action by a system operater, on their face value alone. On this parameter, for example, the taxi shows up poorly in comparison with the other two systems. However, in fact, the taxi carries the highest volume of the three systems. Other considerations undoubtedly enter the picture as far as consumer choice is concerned. The taxi, for instance, offers "to the door" service at the travelers' ultimate destination. This convenience factor may account for its popularity despite its comparatively low position on the service equal value continuum.

Another use to which this method can be put is to examine the effect of any contemplated fare or trip time changes.

## Summary

In summary, a method for comparing certain economic aspects of any two transportation systems has been developed. Essentially, it permits the comparison of systems along the parameter of value of service produced. The value of transportation to an individual is assumed to be, in part, a function of the value of the time involved. Means were devised for determining the value of service for any value of time.

## Chapter 4. Psychological Factors

Psychological factors are of direct relevance and importance to airport transportation simply because the "load" consists of human beings engaged in some form of purposive behavior and who have the capability of free choice among alternatives available. Viewed from the point of reference of the individual traveler, a trip involving air travel can be considered a purposive set of actions which are instrumental to the goal of changing one's location from one place to another. The would-be traveler at some point in time is at his home, office, hotel, etc., with the intention of taking a series of actions which will result in his being at some other home, office, hotel, etc. at some future point in time. Important for the present problem is the fact that almost <u>no traveler has the primary purpose of going from one airport to another</u>. The travel between two airports is only one link in a series of travel links between the point of local origin and the point of local destination. For the traveler--if for no one else--airport transportation is a necessary and integral part of his <u>goal-instrumental actions-goal achievement</u> chain of behavior.

Human choice behavior is involved in this behavior chain in at least two ways pertinent to the problem at hand. First, in respect to the choice of air travel itself as against competing modes, it is obvious in the extreme case that if the traveler could not get to the airport, he would not choose to travel by air. In the less extreme cases, it appears safe to assume that to the extent getting to and from airports vitiates or enhances the advantages of air travel, it will be a factor influencing the

choice of air travel.[1] Second, where alternative airport transportation is available, the traveler will choose that mode which he perceives as maximizing the fulfillment of his needs. Our interest is in both forms of choice behavior. The first influences the total load to be moved by airport transportation and the second has influence on the characteristics of airport transportation modes which are most suitable from the traveler's point of view.

Psychological factors as used in this report refer to the determinants of individual choice behavior as concerns transportation modes.

These psychological factors are by no means independent of the other factors already discussed. The kinematic factors are pertinent aspects of choice behavior; engineering factors are also; economic factors concerned with costs to the consumer are key elements of choice behavior. Thus, psychological factors represent not a separable set of considerations, but rather they are interwoven will all aspects of transportation. Nonetheless, as with the other factors, to discuss them coherently it is necessary to focus on the particular aspects of interest to the relative

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[1] One study has shown the effect of distance of the airport from the city on air traffic. The air travel market at Detroit, 21 California airports, Dallas, and Buffalo was examined. Detroit, for example, showed more than a 40% loss in the available market associated with changing the airport from 6 to 31 miles from the city (58). The general finding, supported by the data from the other cities, could be interpreted with respect to airport transportation. The question could be raised as to what effect would have occurred if highly effective airport transportation had been introduced along with the change in airport site.

exclusion of the others. So doing is not denying the essential interrelatedness of all the factors, but is only admitting that each one can not be discussed simultaneously--and that the function of analysis is to identify parts and examine them closely.

## Determinants of Choice

When we ask, "What determines a person's choice of travel mode?" we immediately confront the problem of unconscious versus conscious determinants. The traveler's choice may be determined by unconscious factors of which he has no awareness, or his choice may be equally a function of completely conscious factors which he can readily report. Unquestionably, there are elements of both in his choice. The problem is quite different, however, between the two cases. If noise, for example, is found to be related to mode choice, it is possible to measure noise for any system and measure noise tolerance of people. If, however, prestige is found to be related to choice of mode, it is difficult to define prestige very precisely in the first place and to measure it in the second.

Nothing systematic or comprehensive, and very little at all has been written about this subject. This neglect seems odd in view of the very nature of human travel. Transportation is one of, if not the largest industry in the world. Its resources are continually being poured into the effort of providing more desirable services and yet almost no basic knowledge exists concerning why people choose one mode instead of another or what characteristics of a mode of transportation are most determinant of their choice.

From the studies that have been done and from inferences from relevant materials, the attempt is made here to summarize what can be said about the determinants of mode choice behavior.

There are two more or less logical antecedents of mode choice determinants--trip purpose, and mode availability. In the conception presented here, trip purpose and mode availability are choice determinants but they are logically prior to, and somewhat different from, other determinants. In a sense, they set the limits within which other determinants operate. In the discussion to follow, the other determinants are grouped under five headings:

Trip Time — Price

Comfort — Safety

Associative Meaning

The first four are relatively objective and capable of measurement within the present state-of-the-art. The fifth, associative meaning, has more to do with unconscious motivation and is less susceptible to quantitative treatment.

The relative importance of these determinants is unknown. One interpretation of the partial data available would, however, suggest that of the first four, trip time considerations are by far the most important; comfort and price considerations are about equal, but even combined are less important than trip time. Safety considerations appear to be of minor importance, but this would probably hold true only as long as safety differences between modes are not great. No information is available on the relative importance of associative meaning, although this will be discussed further.

Trip Purpose. The purpose of the total trip helps define the nature of the goal toward which the trip behavior is directed. In this sense, it is logically prior to other considerations and it delimits the bounds within which the other factors have influence. Travel for the enjoyment of travel differs markedly from the trip to keep an important appointment, reach a dying relative, or change one's place of residence. Each different purpose potentially implies a different ordering of the importance of the several influencing factors. For one kind of trip, speed is of overwhelming criticality, whereas for another it offers no special advantage. Fare or comfort may, to the same person, carry weight of different importance depending upon the basic purpose of the trip.

Travel to and from the airport is only one part of the total trip. It is the purpose of the total trip to which we are referring.

The 1957 National Travel Market Survey (425) is perhaps the best source of trip purpose data. In a national survey, in response to a question about the purpose of their most recent trip by common carrier. the respondents gave the results which are presented in Table III-7. From these data, there appear to be three major classes of purposes. Business and pleasure trip purposes accounted for about 40% each and personal affairs purposes about 16%. These data for all travelers contrast somewhat with the Washington, D. C. survey of airline travelers (see Appendix B) in which about 81% were business purposes, 11% pleasure, and 8% other. Other data largely support the conclusion that air travelers are more likely to have business purposes than travelers by other modes.

It seems apparent that to be able to specify the determinants of mode choice, it is necessary to determine first what the trip purposes of the air traveling population are and the reasons they choose to travel by air to achieve these purposes. Such a procedure would provide a collection of characteristics which make air travel attractive. The thesis argued here is that the more that an airport transportation mode can provide the same or similar characteristics, the more it will be the most preferred mode.

To carry out the above-mentioned kind of analysis would require a special study set up to gather that particular kind of data. No such study has been done, but there is some information available from which at least the outlines of the results which could be expected from such a study can be drawn.

Mode Availability. The availability of different modes to choose among is a logical necessity for choice behavior. Reasons given for choosing a given mode should always be interpreted in view of what modes were available. Whereas in the discussion of trip purpose, it was the purpose of the total trip which was of interest, from this point on the discussion concerns only the airport transportation part of the total trip.

It is not what is objectively available at a given airport, but what people perceive as available which needs to be determined. Travelers are probably more aware of modes available at their home city airport than at other airports. Various local regulations governing airport transport modes tend to cloud the picture as far as what the traveler perceives as available. City taxicabs may deliver at the airport, but not pick up passengers there. Limousines may be scheduled or non-scheduled, stop only at designated points or be free to stop anywhere. Except for the

veteran traveler, the airline passenger terminating his flight in a strange city is likely to have only a vague conception of the different ways he could get to his local destination. For this reason, actuarial figures on mode usage can not be interpreted as indicative of mode choice among alternatives until it is known that the travelers knew of all possibilities.

Trip Time. Trip time is the rubric under which we classify all those factors which influence the total time a given trip takes. These factors include vehicle speed, convenience of arrivals and departures, waiting time, mode changes, etc. In a national survey in 1957, when respondents were asked to give the advantages and disadvantages of different travel modes, 20.3% of the total advantages and disadvantages mentioned concerned convenience of arrival and departure, and 26.7% concerned speed (425, p. 101). If arrival and departure convenience is interpreted as primarily having to do with trip time, then the two together accounted for 47% of the total. In another study, reasons were given for choice between transit and automobile for different kinds of trips in the Chicago area; the reason "less time required" was given more frequently than other reasons by a wide margin (198, p. 48). For trips to the central business district of Chicago, mass transit was chosen more frequently than automobile and the most frequent reason given was "less time". The same reason was given most frequently for trips to outlying areas for which the automobile was chosen more often than mass transit.

In the 1957 national survey mentioned above, when air travelers were asked "How did you happen to choose this way of traveling instead of some other?", 41.4% of the reasons given were classified as "faster" (425, p. 89).

It appears that for travelers in general, and air travelers in particular, trip time is one of, if not the major determinants of mode choice.

For a trip on any one mode between two points, trip time is made up of three components:

| | |
|---|---|
| Travel time: | the time it takes for the vehicle to move between the two points. |
| Waiting time: | the time the traveler must wait before the vehicle leaves the first point and after it reaches the second point. |
| Handling time: | the time required to process the traveler--ticket purchase, check-in, baggage handling, etc. |

In this fact may lie one source of people's antipathy toward changing modes. For each mode used, waiting time and handling time must be added to travel time. Thus, while in a two-mode trip, the sum of the travel time of the two vehicles may not exceed the travel time of any one vehicle for the total distance, the addition of another waiting time and handling time is likely to significantly influence the total time.

The dominance of the private automobile in airport transportation might be considered in the above light. Its use only requires waiting time and handling time if it is parked where the driver can not reach it immediately. Its travel time is equal to or better than almost all competitors. Thus, for travelers with a private automobile available, the trip to the airport is likely to take the least time possible. The helicopter may begin to change this picture, but at present--because it is usually one link in a multi-link trip, and because present headways tend to result in a considerable waiting time--it probably does not change the picture noticeably when the total number of users of an airport are considered.

Comfort. By comfort, we mean the degree of physical and mental ease experienced by a traveler as the result of the characteristics of the vehicle in which he is riding. It includes such factors as noise, vibration, cleanliness, spaciousness, privacy, lack of annoyance, restfulness, convenience with children, etc. Matters of comfort accounted for 17.2% of all the advantages and disadvantages mentioned in the 1957 survey previously cited (425, p. 101). This was a slightly greater percentage than accounted for by price. The Transportation Usage Study on Chicago found a significant effect of not having a seat available and the necessity of making a transfer on a group who had a choice between traveling by private automobile and transit facilities. In the same study, "comfort" was given as a reason for choice next most frequently to "less time" (198, p. 51).

Baggage handling can be considered as part of comfort. The air traveler more often than not carries baggage and for that reason, airport transportation should consider its load as the passenger plus his luggage. This factor alone may account in large part for the unpopularity of mass transit means for airport transportation. They all require the passenger to lug his own baggage, no provision is made for its convenient storage while riding, and he must off-load, carry, and load it himself at every transfer point. This is inconvenient for all travelers and impossible for some.

Here again, the convenience in this regard afforded by the taxi and the private automobile undoubtedly plays a significant role in their popularity. The limousine in its usual form is not a one-link trip for most passengers and, therefore, offers this advantage only to those who originate or terminate at their stop points. Helicopters suffer the same

drawback as the limousines except that through-checking of baggage is possible in some cases, which eliminates baggage handling on one end of the trip. Through-checking of baggage is also being practiced with other modes in those cases where a downtown check-in office is available. Under these conditions, the passenger checks in at the downtown terminal, leaves his baggage there, and is transported by limousine or other means to the airport.

Price. Out-of-pocket costs are frequently mentioned as a primary determinant of choice. The Chicago Transportation Usage Study, however, found that when the choice lay between transit and private automobile modes, at the point of equal costs, only 5% of the trips were made by transit; when transit costs are 1/2 automobile costs, 15% of trips are made by transit, and when the cost of transit is 1/10 that of the automobile, 60% of the trips are made by transit (198, p. 49). These data would seem to indicate that while cost is a factor related to choice, it is neither a simple relationship nor the dominant factor.

In the 1957 travel market survey, price considerations accounted for 15.6% of the total number of advantages and disadvantages of various travel modes named (425, p. 101). Price should be considered in the light of several circumstances. First, for a large percentage of business trips, travel expenses are not borne by the traveler personally, and they would therefore be expected to play a somewhat less salient role than if they were. Second, price is likely to be a major consideration only when there are large differences between available modes which difference is not reflected sufficiently in trip time or comfort differences. This consideration has already been suggested by the Chicago data discussed above in which when the costs of a trip by automobile and by transit were equal, 95% of the trips are made by automobile.

Safety. As a choice determinant, safety considerations reduce essentially to fear. Some people are afraid of some travel modes and this fear may be determinant in some cases. With the travel modes now in use, fear of flying is the most frequent fear. How deep-rooted this type of fear is or how widely it is distributed in the population is not known, although some estimates of the frequency of fear of flying have been surprisingly high. However, since the population transported by airport transportation modes is already a "flying" one, then this consideration applies mainly to the choice of air travel in the first place.

In the 1957 survey, safety considerations accounted for 5.2% of all the advantages and disadvantages given for all travel modes (425, p. 101).

Associative Meaning. This term was coined to encompass those more-or-less unconscious factors which play a part in the choice behavior of humans. Included here are factors such as prestige, or making an impression on someone. By associative meaning, we intend to denote what traveling by a particular mode conveys to oneself or to others about oneself. Concerning these factors, it is not feasible to rely for information on travelers' own reports. In fact, there is no source of reliable information to which exception can not be taken. Some discussion, however, appears in order because it seems all too evident that such factors play a significant role in travel habits--and consideration should be given to them in the design and evaluation of transportation systems.

"Are differences in socio-economic status reflected by mode of travel?" is one kind of question that can be raised. In regard to income, this appears to be true in the United States although less true, perhaps,

in New York City. In many cities, mass transit tends to be regarded as the mode of the "lower" classes and therefore ruled out as an available mode by those who do not consider themselves members of the "lower" classes. This appears to be an area into which little inquiry has been directed; and yet, potentially, it is a factor of far-reaching significance for the transportation industry.

Most of the speculative materials on the psychological significance of transportation modes have concerned the automobile. We have seen, in Part I of this report, the position of dominance the automobile holds over all other travel modes and its spectacular rate of proliferation. We have seen also the dilemma into which this proliferation is leading mass transportation. It is, therefore, not inappropriate to summarize some of the views that have been expressed in the attempt to explain the phenomenon the automobile has become in our society.

Until the automobile age, the American lived in a closed, or "sacred" society. Here he was known to his neighbors and subject to their constant scrutiny and approval or disapproval. With the mobility conferred on him by the automobile, he has moved into an open, or "secular" society, where he enjoys the freedom of anonymity (451, p. 98). Since this freedom is pleasant to him he cherishes the means whereby he obtained it. The means has become a symbol of what is to him a better life. He will not move back from it to such another means as rapid transit with its accompanying associations with social bondage.

The automobile is a status symbol. It has become, says S. I. Hayakawa, "the most important non-linguistic symbol in America today." The American equates his automobile with success. Buying a newer,

more expensive car is a step upward on the ladder. Being a two-car family is a distinction in terms of advancement (451; 452, p. 218).

The automobile is a sex symbol. The average American male is haunted by at least occasional fears of sexual inadequacy. Rocketing down the highway in a high-powered car, he experiences a feeling of mastery in space and time which compensates for his feelings of inadequacy in another sphere (453; 452; 454, p. 79).

The automobile is a symbol of adventure. In a complex and highly routine civilization it is difficult to find physical adventure. Considering his frontier past, the American finds the automobile to be an equivalent to the cowboy's horse and the trader's canoe. Weaving in and out of traffic on a freeway gives him a taste of physical "derring-do" without taking him too far away from his necessary daily routine (451, p. 99).

The automobile is a safety valve for feelings of aggression. Our civilization, through its speed and complexity, is both inhibiting and frustrating. On the highway there is relief for repressed hostilities. The other driver may, for example, serve as a figure image of the boss (451, p. 98-99).

Unfortunately, it is most difficult to pin these considerations down to things which can be measured and taken into account as determinants of mode choice, and no attempt is made here to do so. They serve, however, as a reminder that mode choice is not a completely rational process and that factors beyond those of purpose, availability, trip time, comfort, price, and safety need to be considered.

## Quantifying Psychological Factors

Considerable research work will be necessary before the psychological factors can be reduced to quantitative form of the kind suggested in the introduction to Part III (see Figure III-2). Actually, a number of indices can be described, but what is uncertain is how to interpret them. For example, trip time can be determined along the lines described in the chapter on kinematic factors; but what a trip time difference between two systems, which also differ in terms of comfort and price, means can not be stated precisely without further study.

It has been seen that the choice determinants described depend for their meaning upon characteristics of the traveling population, and these characteristics are likely to vary from city to city. A study is required which would relate the characteristics of the traveling population to the characteristics of the available modes. Such a study could provide us with fairly precise information on the relative weights that should be assigned to the various factors. For a given city, the following information about the population of air travelers would need to be established.

(1) Local origins and destinations.

(2) Trip purposes.

(3) Mode availability.

(4) Income distribution.

(5) Modes chosen.

In each of the modes available, the following would need to be determined.

(1) Trip time.

(2) Comfort indices.

(3) Price.

(4) Safety considerations.

If the above information were obtained in the proper manner, it would be possible to analyze the data to determine the relationship between characteristics of the mode chosen and characteristics of the choosing population. Only then would we be in position to assign relatively precise weights to the several factors involved.

Such a study has not been done, however, and we are therefore in the position of being able to define and measure a number of determinants of choice without being able to assign weights to the different factors with any degree of certainty. The evidence that has been presented suggests the over-riding importance of trip time and the secondary--and about equal--importances of comfort and price. However, it should be clear from the discussion that these weights can only be taken as general guide lines and are subject to a number of dependencies which are ignored in such simple statements.

A number of indices of characteristics of modes related to mode choice can be defined quantitatively. The following paragraphs describe these indices.

Trip Time. Trip time is defined as travel time plus waiting time. It can be determined for a trip between any two points, and it can be expressed summarily for a collection of trips between the points of a network. Trip time can be measured empirically or it can be generated from other data. The material on kinematic factors in Parts III and IV describe the procedures for producing this measure. Essentially, it is a distribution of the number of passengers over trip time. Figure III-4

page 148) shows an example of such a trip time distribution. By knowing this distribution for the trip a passenger is considering, it is possible to describe his expected trip time in probability terms.

Comfort. A number of factors reflect comfort. Among these are: noise level, vibration (roughness of ride), mode changes required, services provided (baggage handling, ease with children, etc.), and spaciousness.

1. Noise level. While noise is seen to intensify the airport transportation problem, it also serves to hinder its solution because some of the most promising solutions depend on the use of extremely noisy vehicles, e. g., elevated or subway railways and V/STOL aircraft. Noise is of concern to both the users and non-users of a transportation system. Passengers are concerned with the noise level within the vehicle, while non-users are concerned with the noise level in their communities due to the system. Many studies, running the gamut from basic research to broad planning, have been focused on the solution of the noise problem. In one basic study to determine acceptable noise levels, the measurements of sound levels in three octave bands from 600 to 4800 cycles per second were averaged to obtain a single figure--the Speech Interference Level--that is related to voice communications at various distances (455). Specifically, it was found that a speech interference level of 70 db will permit conversation in raised voices at a distance of 2 or 3 feet. The Toronto Transit Commission adopted a design limit for noise levels in the Toronto subway which was close to this speech interference level (317).

Figures III-16 through III-19 present data which is pertinent to the determination of noise indices. The acoustic power, in watts and decibels above a given reference, is plotted versus typical sources in Figure III-16.

FIGURE III-16

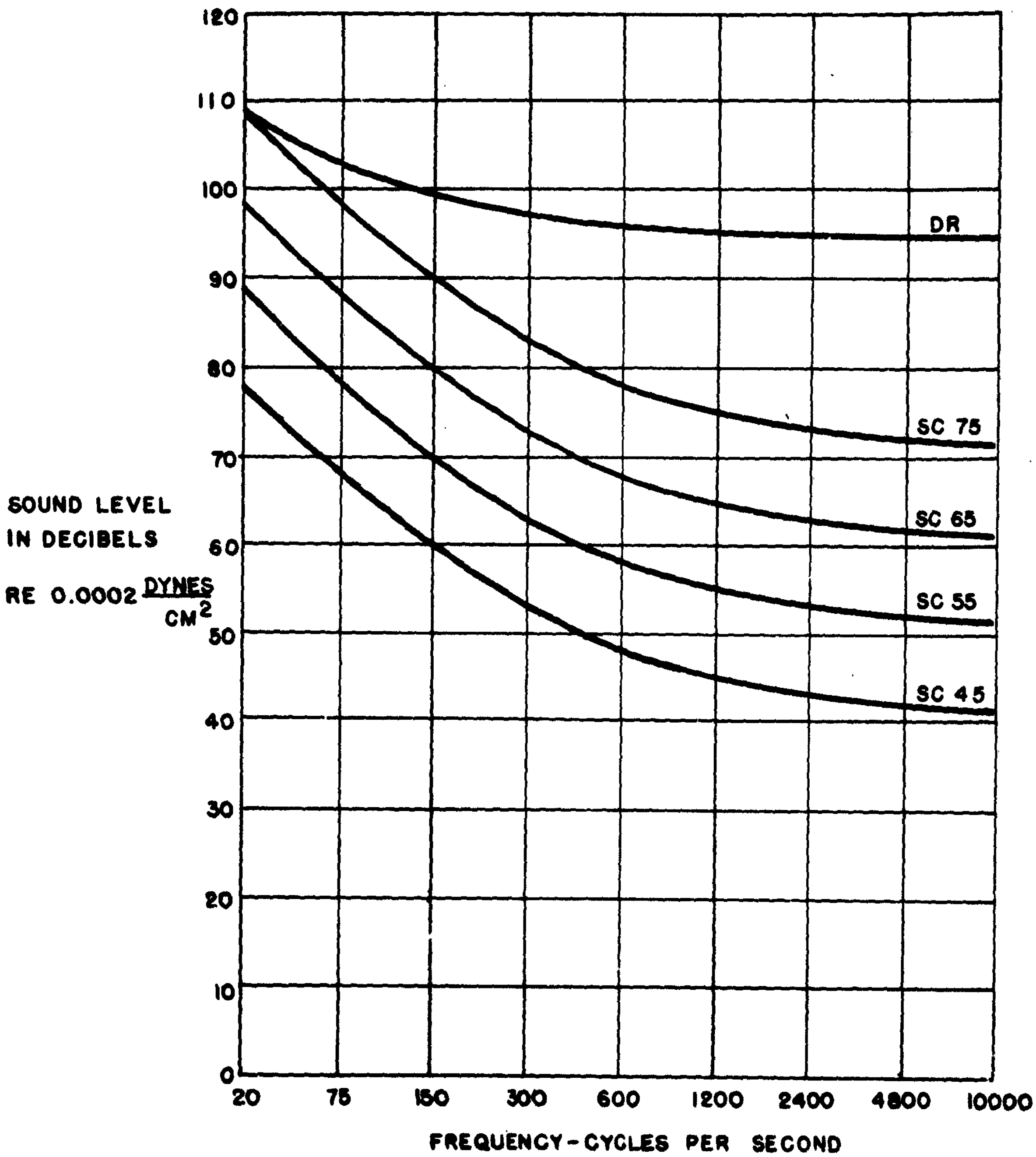
Acoustic Power

| Acoustic Power (Watts) | Power Level (DB Re $10^{-13}$ Watts) | |
|---|---|---|
| $10^6$ | 190 | |
| | | Proposed Jet Engines |
| $10^5$ | 180 | |
| | | Turbo Jet Plus Afterburner |
| $10^4$ | 170 | Turbo Jet Engine, 7000 lb. Thrust |
| | | Super-Constellation (Takeoff) |
| $10^3$ | 160 | |
| | | DC-3 (Takeoff) |
| $10^2$ | 150 | |
| 10 | 140 | Large Orchestra |
| 1 | 130 | |
| $10^{-1}$ | 120 | Blaring Radio |
| $10^{-2}$ | 110 | Automobile on Highway |
| $10^{-3}$ | 100 | Voice--Shouting |
| $10^{-4}$ | 90 | |
| | | Voice--Conversational Level |
| $10^{-5}$ | 80 | |

Source: (52)

FIGURE III -17

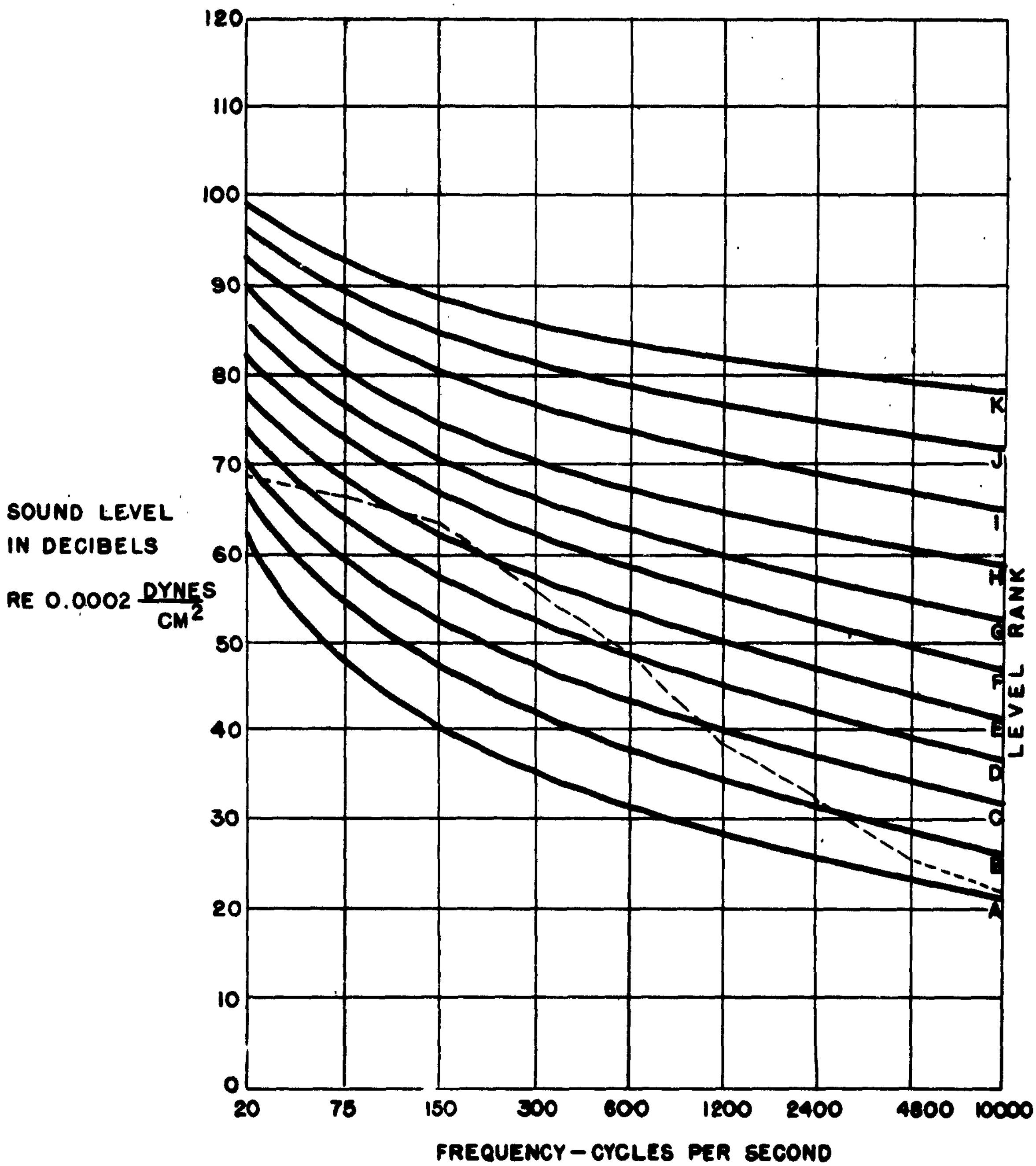
SPEECH INTERFERENCE LEVELS OF NOISE




SOURCE (20)

FIGURE III-18

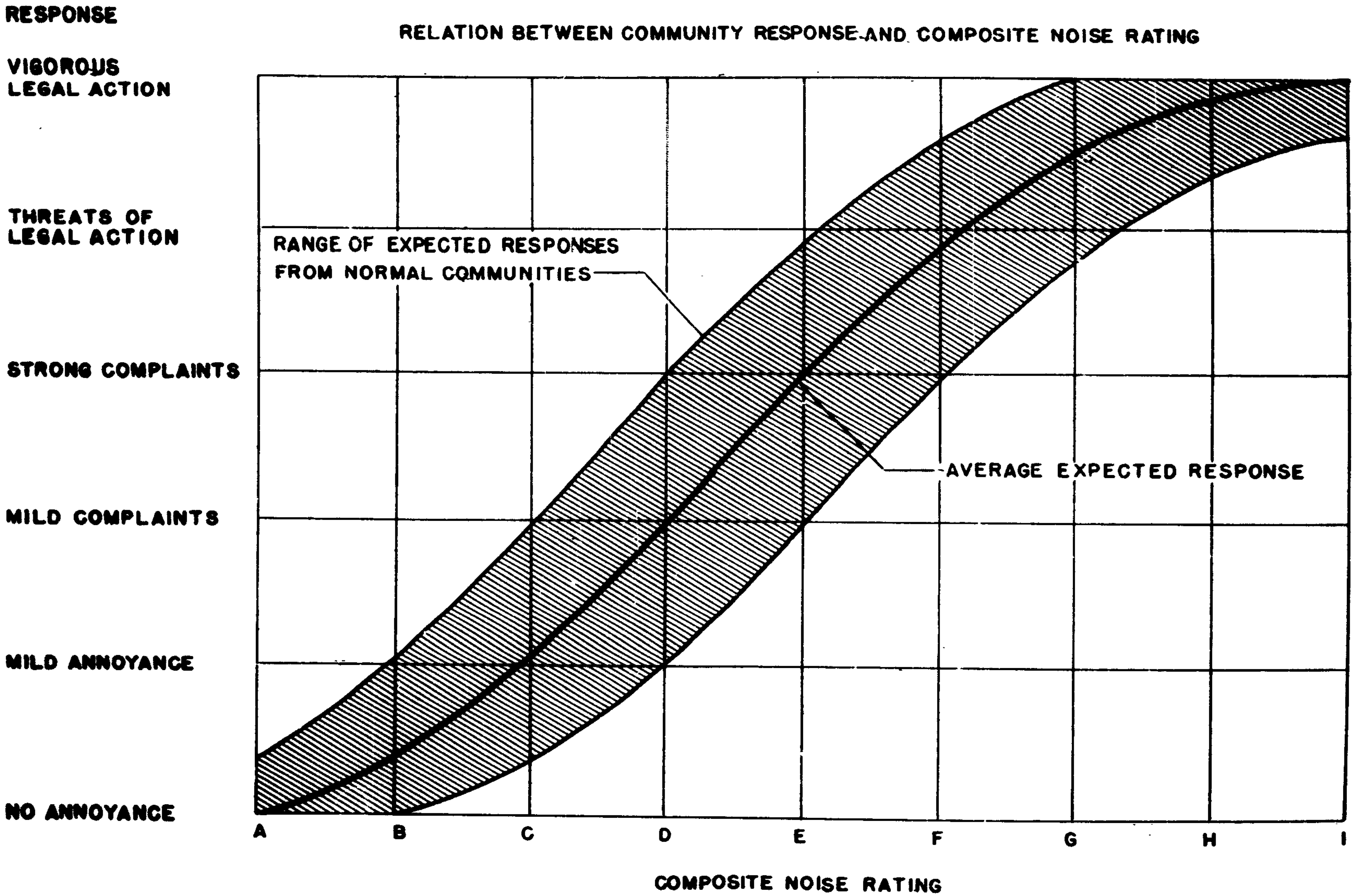
NOISE LEVEL RANK




SOURCE (20)

FIGURE III-19
COMMUNITY RESPONSE TO NOISE

RELATION BETWEEN COMMUNITY RESPONSE AND COMPOSITE NOISE RATING




SOURCE (20)

The decibel reference level is $10^{-13}$ watts; therefore, a power level of 130 decibels corresponds to an acoustic power of one watt. Suitable investigations are required to locate the position of additional vehicles on this acoustic power scale. Figure III-17 is a plot of speech interference levels as a function of sound pressure level and frequency band of the noise. Speech communication at a relaxed conversational level will be highly intelligible at a distance of ten feet if the noise does not exceed a speech interference level (SC) of 45. Such speech communication is marginal if the SC exceeds 75.

A study conducted by the Acoustics Laboratory of the Massachusetts Institute of Technology relates the probable response of a community to a "composite noise rating" (52). The composite noise rating is defined graphically as a function of sound pressure level, frequency band of the noise, and several other influencing factors such as time of exposure, length of exposure, connotation of noise, extent of conditioning of the community, etc.

Figures III-18 and III-19 present data used in this evaluation of community response. A "level rank" is defined as shown in Figure III-18. The level rank is then modified to account for other factors which influence community response. The "composite noise rating" thus obtained is used in conjunction with the graph of Figure III-19 to determine the probable community response.

2. <u>Vibration--roughness of ride</u>. Vibration can be measured in terms of the amplitude and frequency of the resulting acceleration; hence, a vibration index could be based on these absolute measurements, and systems can be graded accordingly.

3. Mode changes required. It is assumed a trip without mode changes is more comfortable than one with mode changes. A simple index for a system can be derived which is defined as the ratio of the number of passengers who require a mode change to the total number of passengers who use the system. (A passenger who requires two mode changes would count as two in the denominator.)

4. Services provided. This is essentially a question of baggage handling and probably is treated qualitatively as easily as it would be if quantitative indices were to be devised. A simple description of what the passenger does with his baggage should suffice.

5. Spaciousness. Space available can be measured in terms of volume per passenger, area per passenger, seat width, or seat spacing. The latter two measurements appear to give the best indication of spaciousness. It is suggested that a space index be defined which is equal to the normalized product of seat width and seat spacing. The normalizing factor might be the largest value of the product obtained for all systems considered.

Price. We refer here to out-of-pocket costs for the trip to or from an airport. Costs obviously vary as a function of the location of local origins and destinations. For a given set of local origin and destination points, the average out-of-pocket costs can be determined. They would include the costs of all modes required to make the trip. The average out-of-pocket costs for the limousine, for example, would include the limousine fare and the costs of whatever mode must be used between the limousine stop and the actual origin and destination. To compare systems, the same set of local origins and destinations must

be used to calculate the average out-of-pocket costs. In some cases the total set of origins and destinations may be of interest; and in others, particular subsets may be examined.

## Chapter 5. Regulatory Factors

Regulatory factors have pervasive influence in all forms of transportation, but they represent a different kind of factor than those previously discussed. Regulation is more a characteristic of the situation in which a system operates than it is of the system itself. Further, regulations and policies are subject to change by political decisions and can not be considered unalterable characteristics of the situation. Our approach to regulation differs, therefore, from that taken in regard to other factors.

Airport transportation is faced with the problem of having to operate under multi-jurisdictions and it is this fact which is considered to be the most critical aspect of regulation for the problem under consideration.

Some 51 metropolitan areas may be classified as extending across, or bordering on, one or more state lines. These would account for more than 55% of the total United States metropolitan area population (309, p. 203). Roughly 60% of the United States population live in the 174 standard metropolitan areas as defined by the Bureau of the Census; namely, in a county or group of continuous counties which contains at least one city of more than 50,000 inhabitants--with the surrounding area essentially metropolitan in character, and socially and economically integrated with the central city. Twenty-three of these 51 metropolitan areas extend across state lines. The 23 account for about 42% of the total United States metropolitan area population. Six of these 23 areas are "large hubs" (of the 1959 list of "large hubs") as defined by the Federal Aviation Agency. But these six "large hubs"

accommodated 42.4% of total aircraft departures from large hubs in 1959. In the 23 metropolitan areas that cross state lines, 1/5 of the population lives "on the other side of the state line".

For airports which serve areas encompassing more than one political subdivision, to change existing systems or to institute new systems designed to deal more effectively with airport transportation requires the cooperation and coordination of a large number of agencies, authorities, and state, municipal and local governments. The sheer amount of effort required to obtain such cooperation is an effective deterrent to changes new approaches to airport transportation. This situation is compounded by the fact that airport transportation represents such a small fraction of the total traffic within any urban area that, for cognizant authorities, it does not constitute a problem of major concern compared with the other problems which fall within their areas of responsibility.

If effective steps are ever to be taken to improve airport transportation on a broad scale, it would appear that the first of such steps would be to establish the jurisdictional pre-requisites. An examination of some of the efforts in this direction is, therefore, in order.

Virtually every form of mass transit is directly regulated in some way. Whether mass transit is on the surface, below or above ground, interstate or intrastate, one or more authorities are there ready to help or impede. Who regulates airport transportation, however, is sometimes difficult to determine. However unique its problems may be, airport transportation is an integral part of the whole metropolitan transportation problem. This problem is complicated in most metropolitan areas by the absence of unified administration. Effective urban transportation may not be achieved without a political structure which makes possible a

unified approach to the planning, financing, and operating or regulating of the transportation system as a whole. The concept that a unified approach is necessary to the solution of any level of transportation problem is gradually being brought to light regarding federal transportation policy; i. e., the recent Landis report regarding unification of federal transportation policy and agencies. The Dade County, Florida, experiment is a notable example of an "area government" experiment. For a detailed study of this problem see Dixon and Kerstetter, "Adjusting Municipal Boundaries--The Law Practice in Forty Eight States" (456). The Washington Metropolitan Area Transit Regulation Compact recently approved by Congress is an example of an interstate agreement to solve part of a metropolitan transportation problem. Inter-municipal agreements at an intrastate level are sometimes not even allowed by state statute. For a detailed state-by-state summary of such statutory authorization, see "Report of Committee on Inter-Municipal Cooperation" (457).

The source of authority for regulation of airport transportation is primarily a function of two variables: (1) the location of the metropolitan area with regard to internal and external political boundaries, and (2) the location of the airport in relation to the metropolitan area or areas to be served. To elaborate, the following observations are relevant. Examples of jurisdictional situations may illustrate these points. Existing transit service in Washington, D. C. metropolitan area, in order to be regulated on a uniform basis, would require a merger of Virginia, Maryland, and the District of Columbia transportation regulatory bodies (including several county and city bodies operating in the Virginia and Maryland portions of the area), and a cessation of jurisdiction of the Interstate Commerce Commission. (This has been partially achieved.)

In order to achieve the same purpose in Dade County, Florida, however, the problem was somewhat less complex. The Miami metropolitan area population is contained primarily in one county. Only smaller political subdivisions of the same state and county had to cooperate. The number of regulatory authorities involving airport transportation may also depend on the location of the airport with regard to the metropolitan area. A downtown airport (e. g., San Diego, California) will have almost the same regulatory problems as any other metropolitan transportation system in the same metropolitan area. The "beyond suburbia" airport (e. g., the Durham Airport in Raleigh, North Carolina) will have to deal with additional regulatory agencies.

Once the geographical location of the airport is established, further "choice" of regulation is available, depending on the transportation media. Air transportation (helicopter, for example) will be subject to federal regulation--by the Civil Aeronautics Board and the Federal Aviation Agency--regardless of what additional local regulatory problems are involved. Beginning in 1926, the federal government--under the Air Commerce Act (44 Stat. 568)--has "complete and exclusive national sovereignty on the air space" over this country. On the other hand, local taxi service in a metropolitan area located in the middle of a state is involved only with the regulatory bodies in each political subdivision through which the taxis must travel. The interstate aspect of air travel ends at the airport. For example, the Fair Labor Standards Act has recently been held not to apply to support cabs at an airport (458).

Beyond the geographical location of the airport and the media of airport transportation to be used, there are several aspects of regulation which must be explored. These aspects can be classified as: rates,

safety, zoning, labor, taxes, licensing, and planning. One or more regulatory bodies will be encountered in each of these areas. To illustrate by a hypothetical example, assume that the management of Dulles International Airport decided that a monorail from the airport terminal to a point in downtown Washington, D. C. would be an ideal solution to their transportation problems. The Acme Monorail Company, which is to build and operate the monorail, plans to put five stops on the line between terminal points; two in Fairfax County, Virginia, two in Arlington County, Virginia, and one just inside the District of Columbia. Rates and safety aspects of the terminal to terminal portion of the operation would be subject to Interstate Commerce Commission regulation (or regulation by some federal agency). The newly created transit authority in Washington, D. C. would not have jurisdiction because the terminal building of Dulles Airport is just outside the standard metropolitan area. The agency created by the Washington metropolitan area transit regulation compact would regulate rates and safety for the Fairfax County to District of Columbia portion of the operation. Concepts of safety and methods of determining cost of service might be entirely different for these two agencies. Acme will have to adjust to these difficulties. The monorail may not be able to go in a straight line because of different zoning requirements in the political subdivisions through which it must pass. The "master plan" of each area (if they have a master plan at all) differs. Each little group is almost autonomous as a matter of practical politics. Because of the interstate nature of the operation, federal labor law rules and regulations will have to be observed in addition to Virginia and District of Columbia labor laws not in conflict with the federal ones. Taxes ranging from real property taxes to income taxes will be levied by the various jurisdictions. One jurisdiction may allow much more favorable depreciation methods, etc.

A license, certificate, or franchise will have to be obtained from more than one source. The standards may be different for each one. Last of all, transportation system planners in one of the several jurisdictions may be avidly against monorails--thus making the entire project impossible.

Additional regulation of airport transportation may take the form of self-regulation by contract. In order to insure adequate transportation, most airports find it necessary to grant exclusive "franchises" to taxi and/or limousine companies. It is interesting to note that San Diego, California has a downtown airport and that transportation is handled by the free market of taxis, buses, etc., without need for the airport to grant exclusive franchises. When the airport operator grants a franchise, he usually insists on the right to regulate the activities (including rates charged) of the transport operator. A detailed summary of the ground transportation "contract" regulatory provisions at 48 major airports may be found in the Airport Operators Council "Revenue Sources Handbook--Ground Transportation" (459). (Unfortunately the study is available only to members of the Council.) At least one airport at all large hubs, except Buffalo and Pittsburgh, are included in the study.

The physical aspect of airport transportation reveals that regulation is integral to the regulation of the total metropolitan transportation system. Whatever the special needs of airport transportation, its regulation must be treated as a part of the total metropolitan transportation problem if it is to be treated effectively. Virtually all authorities agree that a unified approach is the only hope for effective solution. Whether the unified approach is achieved by area government, annexation, or

cooperative agreements is not important except from a political standpoint. This unified government authority must not only be comprehensive from a geographic standpoint, but should also encompass every media of local transportation.

This does not mean that national standards for safety, etc. must bow to local rules. It does mean that where helicopter, train, bus, etc. service is performed within a metropolitan area, the area government authority--where it exists--should be autonomous as to policy regarding the giving of franchises, the setting of rates, and related matters.

# PART IV. MEANS FOR THE EVALUATION OF AIRPORT TRANSPORTATION SYSTEMS

## Introduction

There are two primary goals of this study. First, to identify and describe the airport transportation problem; and second, to devise means for evaluating airport transportation systems in particular situations. Parts I and II of the report were intended to achieve the first goal, and Parts III and IV to achieve the second. In Part III, the attempt was to analyze the several major sets of relevant factors to isolate those parameters which could provide a meaningful basis for evaluation. The purpose of Part IV is to summarize and recapitulate the evaluative parameters to which our analysis has led.

The second main goal of the study--means for evaluation--has been achieved to a degree less than would have been possible if such serious lacks of basic data and fundamental knowledge of relationships among key factors had not been encountered. However, part of the value of the present study is considered to be the specification of information which is required, but presently unavailable.

The breadth of scope of the present study has meant, almost necessarily, that more progress could be made in some areas than in others. The work on kinematic factors, for example, has been carried further than the work on other factors. However, it is believed that this is particularly appropriate in that the kinematic factors are basic to all other considerations.

The next chapter summarizes the basic data requirements. It is followed by a chapter which delineates the computations required for

generation of the kinematic parameters and presents the bases of a computer program to accomplish these computations. The evaluative parameters are then summarized.

## Chapter 1. Basic Data Requirements

The airport transportation situation in any city can be studied for either or both of at least two purposes:

(1) To assess the present situation and to identify particular problems.

(2) To evaluate the effect of proposed modifications in the present systems or the introduction of entirely new systems.

Both purposes require essentially the same information about airport transportation in the city being considered. Obtaining these required data is the first step in any consideration of airport transportation in a particular city.

Three types of information are needed:

(1) trip characteristics;

(2) mode characteristics;

(3) traveler characteristics.

### Trip Characteristics

The pattern of local origins and destinations can be specified in terms of the geographic location of the points between which the airport trips occur, and the number of people traveling each way between each pair of points distributed over time of day. Such a specification is given by the kinematic requirement functions.

These functions can be determined for all airport users of all airports in a given city, for users of only one airport, or for a

particular segment of users at one or more airports, depending upon the question which is being asked. The precision with which each point is identified is also a function of the question asked. Ultimately, in every case, the point involved is a street address or doorway, from which--or to which--an individual is traveling. For most cases, groups would be formed of a number of addresses close to each other and the group would be identified as a single point. How this grouping is done, again, depends upon what question is being asked.

Another variable involved is the time period of reference. The data utilized may describe the situation at the present time or they may be projections (based on present or past data) into some time period in the future.

## Mode Characteristics

By what mode travelers presently make the trips identified above and what characteristics these modes have is another required type of information. It is desirable that the information be obtained in such a way that it can be related to the trip characteristics so that trip and mode interaction can be determined.

At least two kinds of mode characteristics can be conveniently distinguished. First, there are those which describe the passenger's experience in traveling by it. Second, there are the purely physical features which concern the operation of the mode; i. e., power plant, and other engineering features. Data in the first category include: mode or modes, out-of-pocket costs, trip time, waiting time, mode changes, treatment of baggage, etc. Data in the second category include: power performance index, working rates, payload power requirements, etc.

## Traveler Characteristics

The efficacy, efficiency, and desirability of particular systems or system combinations is the result of the interaction among trip, mode, and traveler characteristics. Thus, data are needed about the travelers' making the trips identified above. Information required includes: trip purpose, perceived mode availability, amount of baggage, income, etc.

## Summary of Data Requirements

The present research has indicated the usefulness of the data listed in Figure IV-1 for airport transportation assessment and evaluation. Some of the items listed are, in themselves, evaluative parameters. Others require certain operations on them to generate evaluative information. These data are the information required to start a comprehensive evaluation in a given location. For a particular purpose only part of them may be of interest.

FIGURE IV-1

Summary of Data Requirements

| For TRIPS made on various | MODES by airport | TRAVELERS |
|---|---|---|
| Local origins and destinations<br><br>Number of travelers from each origin or to each destination by time of day | For each trip:<br>Type of mode<br>Out-of-pocket costs<br>Waiting time<br>Trip time<br>Mode changes<br>Capacity: a. vehicle; b. way; c. vehicle-way combination<br>Headway<br>Gross power requirements<br>Working rate<br>Power performance index<br>Payload power requirements<br>Range<br>All-weather capability<br>Noise<br>Vibration<br>Treatment of baggage | Trip Purpose<br><br>Perceived mode availability<br><br>Amount of baggage<br><br>Income |

## Chapter 2. Computational Procedures (and Alternatives) for Kinematic Requirements Functions and Performance Functions

In Part III, a mathematical model relating the kinematic factors was described. Two functions were delineated: the requirements function, and the performance function (see Figure IV-2 (a) and (b)).

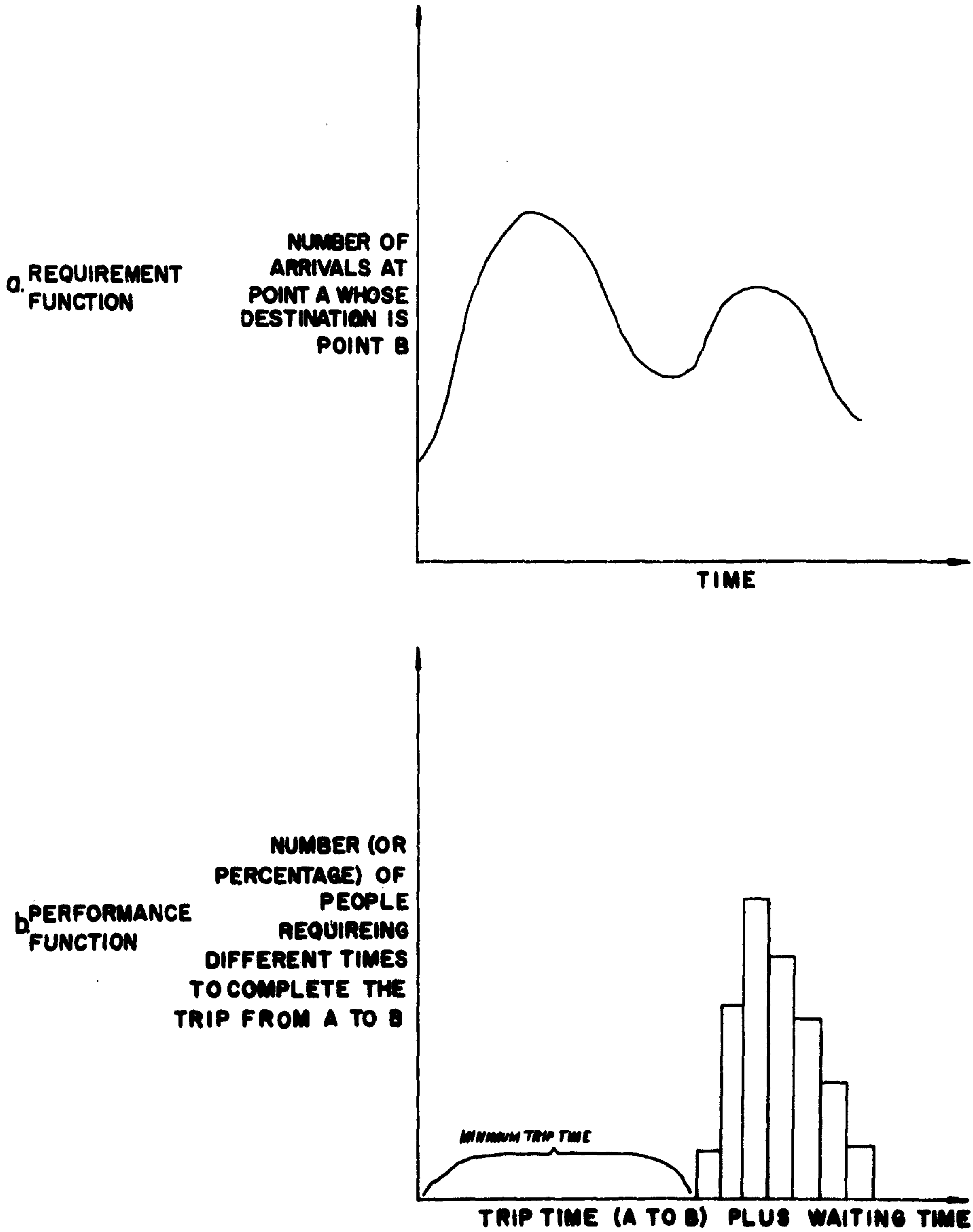
### Determination of Kinematic Requirements Functions

As Figure IV-2 (a) is drawn, it represents some periodic function over a given time interval. As it stands, the period could be anything--hour, day, week, etc. Furthermore, this functional representation could be for a system in-being or a proposed or projected one. It could be used to represent the load for a single run AB, several runs AB + AC + AD, or the sum total of demand or load on all runs in the entire network. The nature of Figure IV-2 (a) depends on what portion of the transportation system it is to represent.

Further alternatives arise when we begin to consider the degree of accuracy, consistency, and certainty with which we can construct such a function. If we were examining a system inbeing to determine the load pattern from A to B on a particular day of the week, for example, we might find by many replicated observations that we can not only determine the mean load for any hour of this day, but also determine how each hour's load tends to be distributed about this mean. In such a case, we would have, not the single periodic function as illustrated by Figure IV-2 (a), but an entirely different set of functions--one for each hour (or each 1/4 hour, or 1/2 hour, etc.) whose abscissas were load and whose ordinates were frequencies of distribution of load.

FIGURE IV - 2

KINEMATIC REQUIREMENTS AND KINEMATIC PERFORMANCE FUNCTIONS



The opposite extreme would be the case where we were projecting or predicting from best available bases, but, nevertheless, doing so under considerable uncertainty. In such a case, rather than attempting to go into more detail than Figure IV-2 (a) does, we might wish to state estimates of what the peaks and troughs might be.

Those are variations on Figure IV-2 (a). What we would use in a particular situation would depend on three things:

(1) Time and resources available.

(2) Availability, reliability, and consistency of data.

(3) Amount of detail desirable.

## Determination of the Kinematic Performance Functions

In order to calculate Figure IV-2 (b) for a run from A to B, it is necessary that the performance function (Figure IV-2 (a)) and the three generic system parameters--vehicle capacity, trip time, and headway--must all be given. Once these four factors are determined, the performance function also is completely determined. If we then change one or more of these four factors we almost certainly change the resulting performance function.

Just about the simplest set of circumstances under which we could determine a performance function are these:

(1) Random arrivals with a constant average hourly rate A.

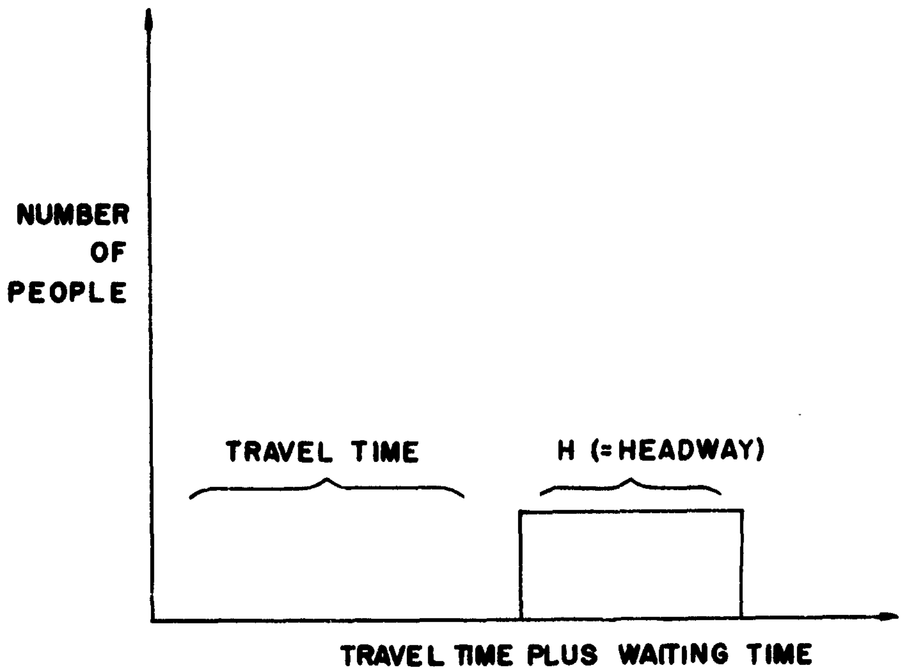
(2) Constant headway H (fraction of an hour).

(3) Vehicle capacity C, large enough so that with given A and H the probability that more than C passengers arrive in H time interval is negligible.

Under these circumstances, the probability is negligible that a vehicle would leave passengers at point of origin for the reason that its capacity was exhausted. This being the case, the entire waiting time of any passenger is less than or equal to time interval H and, since we are considering random arrivals, the distribution of their arrivals over H will average out flat, giving a performance function such as that of Figure IV-3.

FIGURE IV-3

Simple Performance Function




Under these conditions we have the useful relationship,

$$(\text{Travel Time}) + (\text{Headway}) = (\text{Criterion Percentage}) \times (\text{Criterion Time})$$

If the three conditions enumerated above do not all hold, then our problem gets more complicated. If headway is not constant and/ or if the capacity is not large enough so that the probability of being able to take on all waiting passengers is essentially 1, then we can no longer utilize the simple relationships illustrated in Figure IV-3.

However, if the definition of the problem is such that we are working with a constant headway, we will next want to calculate the probability that C, or fewer people, will arrive in H minutes under an arrival rate of A people per hour. If we let

$$\lambda = \frac{AH}{60}$$

we have effectively switched our basic time interval to the period between successive vehicle departures. And the probability, P, of arrivals exceeding capacity, C, during this interval is given by:

$$P = 1 - \sum_{k=0}^{C} e^{-\lambda} \frac{\lambda^k}{k!}$$

If H is variable or if the value of P is not negligible then we will try to utilize the theory of Bulk-Service Queues as developed in (28; 460; 130; 129; 461). If the variation of H happens to be defined such that Bulk Service Queue theory can accommodate it, we can use these techniques to get our waiting time distribution of people. If we then shift this distribution to the right by an amount equal to trip time, we have the performance function we are seeking.

If we could not consider arrivals to be random and at a constant average rate, or if we felt we had to use some distribution of H which

currently available Bulk-Service Queue methodology could not accommodate, then we would have to use Monte Carlo methods.

Random Arrivals. While there is no question that there is a lack of independence among airline passengers arriving and departing since many of them are tied in with each specific plane arrival and departure, there are many "shuffling" effects which tend to mitigate any deleterous effects this lack of independence might have on an analysis which assumed random arrivals for transportation service with a given average arrival rate. At the very least, this matter is subject to an empirical determination for any existing airport. Some of these "shuffling" factors are:

(1) Individual differences in "time-cushion" desired.

(2) Long and variable time required between touchdowns and unloading of different aircraft.

(3) Differences in baggage handling times.

(4) Individual differences in use made of airport concessions.

(5) Varying distances between some baggage points and the point of access to local transportation.

Obviously, this list could be extended.

Constant Arrival Rate. First of all, the distinction between the arrival rate of this section and the more or less random arrivals of the preceding section is the distinction between, for example, the number of arrivals per hour and the way in which the numbers of these arrivals fluctuate minute by minute.

Any arrival rate which we might consider is not going to remain constant indefinitely unless it is determined over such a long period of

time as to be useless to us. We would reasonably expect the hourly arrival rate to be quite different at 4 a. m. from that at 5 p. m. Under some circumstances we might be able to overcome this difficulty without doing great violence to our results and still be able to utilize the analytical methods which have been described. If, by examining the requirements function (arrival rate) with which we were concerned, we were able to make the determination that there were intervals of fairly stable arrival rates, connected by rapid changes to and from these values, then we could utilize methods described on a piecewise basis. That is, we could break the original problem down into several different problems (one for each plateau in the requirement function) and determine the concomitant performance as has been described. We could then either examine these solutions separately, or--more in keeping with our original purpose--simply add them together to get a consolidated performance function after solving it a piece at a time.

Constant Headway. Just as we can use a piecewise breakdown of differing constant arrival rates, so we can use a piecewise breakdown of differing headway (schedule) values or functions. The second procedure is completely analogous to the first. If necessary, we could also handle variable headways on a piecewise step-function basis, using one value in one interval and a different value in the next interval.

Conclusion. If the functions with which we are dealing are so intricate that we can not use any of the simplifying assumptions we have been describing without destroying the validity of results, then we must resort to some type of mathematical simulation of the system. We could then describe the components in statistical terms just as we find or are given them, and play out what we have in order to see what the results

will be. Depending on how fine a mesh or grid we put on the components of our simulated system, and on how large the time periods we covered with it, we might get information on single runs of the model, or several replications might be required for each set of parameters under consideration.

It is quite conceivable that with a given set of parameters and a given requirements function to study, we might be able to apply analytic methods to parts of the requirements function, simulation techniques to other parts of the same function, and combine the results to give us a performance function as in Figure IV-2 (b).

## Absolute Criteria

Given any performance function (Figure IV-2 (b)), it is an uncomplicated matter to calculate the abscissal value for every one of its percentiles. This furnishes us with the means for stating an absolute criterion which any given performance function either does or does not meet. We could use any one, or any group, or all of the percentiles as a framework for stating our criterion. To make this point specific, suppose we were to use the 25th, 50th, and 75th percentiles to state our criterion. Since the objective with which we are concerned is the minimization of time required to transport passengers, our statement of criterion consists of placing a time value on each of the selected percentiles. To continue with a specific example, suppose we assigned the values 10 minutes, 15 minutes, and 20 minutes respectively to the 25th, 50th, and 75th percentiles we have selected for use in our criterion. Now, since we can calculate any percentile of any performance function we have, let us calculate the 25th, 50th, and 75th percentiles of a performance function we

have been given so that we may determine whether or not it satisfies the imposed criterion. If, for example, the values of the three percentiles of the given performance function were 8, 13, and 18, then it would satisfy the criterion (of 10, 15, and 20) with some margin. If, on the other hand, the values had been 3, 5, and 21, or 12, 13, and 14, the performance function would have failed to satisfy the criterion.

## Computer Logic Flow Diagram

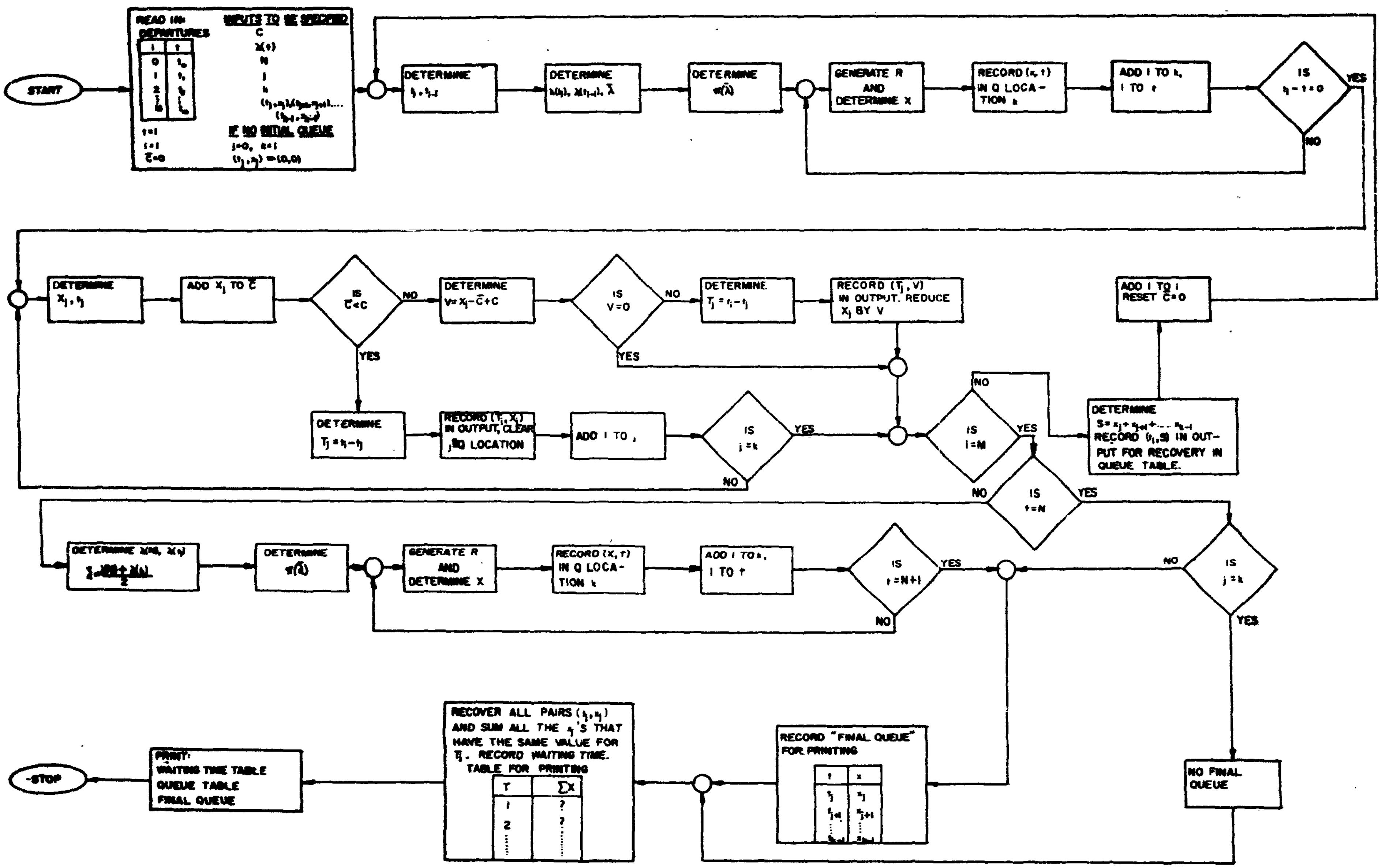
It would seem clear that the procedures described could be carried out by hand calculation methods only in the simplest of cases. For the model to provide general utility, it is necessary to carry out the computation procedures by means of high-speed computers. It was not possible, within the scope of the present study, to convert the procedures into a computer program. If the present research study is carried further, the next step will be to produce a computer program by use of which the kinematic model will be applied in a particular situation. The work so far has been carried up to a logic flow diagram from which a computer program can be written.

The kinematic model is conceived of as the nucleus of a more comprehensive model of transportation systems. The further development of the model depends upon the availability of a computer and the opportunity of trying out what has been developed so far. The logic flow diagram and the explanation of it are presented here for the benefit of whomever may have use of it.

The flow diagram, Figure IV-4, has been designed to calculate the kinematic performance function which has already been described.

FIGURE IV-4

FLOW DIAGRAM SHOWING METHOD OF GENERATING KINEMATIC PERFORMANCE FUNCTIONS



There are two reasons why this aspect is the logical point to begin setting up automatic computation procedures.

A far greater number of calculations are required for this step than are required for any of the others; and, by the time this step is reached, matters of judgment have largely been resolved. Furthermore, this is the type of thing that would have to be calculated many times because it would need to be tried for many sets of parameters. There are three major steps to this process, two of them contained within the flow diagram and one of them external to it.

(1) Arrivals of people are generated and stacked up as a queue.

(2) Vehicle arrivals are considered sequentially and by comparisons among queue size, vehicular capacity, and vehicular and passenger arrival times, the distribution of passenger waiting times is determined.

(3) After this distribution of passenger waiting times has been determined, it merely needs to be shifted to the right by an amount equal to travel time in order to become the performance function.

Explanation of Symbols Used.

t = time. The basis of the entire problem (that has been presented by the flow diagram) is the examination of simulated events as they occur at different times through the period under consideration. As the problem runs, t assumes increasing values, and these values serve to identify the time between events of the problem with which we are concerned. When the problem begins, $t = 1$. When it ends, $t = N$.

N = the total number of time intervals in the period of time we have under consideration. If we considered a full day at half-minute intervals, $N = 2,880$. If we considered an hour at 10-second intervals, $N = 360$.

$M$ = the total number of vehicle departures in the period of time under consideration.

$i$ = a general index referring to the general vehicle departure. When $i = 1$ we are referring to the first vehicle departure. When $i = 7$ we are referring to the seventh departure; when $i = M$ we are referring to the last departure.

$t_i$ = the time of the $i^{th}$ departure. If, for example, $t_4 = 150$, this means that the fourth departure in the period we are studying occurs when $t = 150$.

Q location. A block of locations in the memory is referred to as a set of Q locations. This particular set of locations is used to store passenger arrivals in a queue, and to pick them up as bulk service becomes available. They must be treated cyclically; i. e., the first of the Q locations must be considered to follow immediately after the last. It is difficult, without the context of a specific problem, to say just how many locations would be required. However, something on the order of magnitude of two to four times the maximum difference between any two successive $t_i$'s should generally suffice.

$j$ = index of the first Q location from which passengers are to be picked up.

$k$ = index of the first available Q location at which new arrivals can be stored.

$r$ = index running from $j$ to $k$ inclusive.

$x_r$ = number of people in Q location 1.

$t_r$ = the value that $t$ had when all the people comprising $x_r$ arrived.

$R$ = a pseudo-random number.

$C$ = vehicle capacity.

$\overline{C}$ = the occupied portion of C at any time.

$\lambda(t)$ = passenger arrival rate (a function of t).

$\bar{\lambda} = \frac{\lambda(t_i) + \lambda(t_{i+1})}{2}$ This is just an average value of $\lambda$ to be used throughout an interval between two successive $t_i$'s. This is suggested merely as a means of avoiding a lot of time taken in calculating $\lambda(t)$ and the subsequent $\pi(\lambda)$ for <u>every</u> value of t.

This table is a function only of $\bar{\lambda}$. This table assigns to any given value of R, the pseudo-random number, a particular value of $x$. This value of x signifies the number of passengers who actually arrived for service during any one value of t. An example of what $\pi(\lambda)$ would look like is given by:

| R | | x |
|---|---|---|
| 000 | 500 | 0 |
| 501 | 900 | 1 |
| 901 | 999 | 2 |

If the arrivals in any short time interval may be considered to be random, they may be calculated by:

$$p\text{ (x arrivals in any 1 interval)} = e^{-\bar{\lambda}} \frac{\bar{\lambda}^x}{x!}$$

<u>Inputs to the Flow Diagram</u>. The flow diagram needs the following numerical inputs as parameters in order to function for a particular case.

(1) A schedule of times (values of t) of all vehicle departures, including the number M which is merely the total number of such departures.

(2) Initial queue which includes values for:

$$j, k, t_j, x_j, t_{j+1}, x_{j+1}, \ldots, t_k, x_k.$$

(3) Constants C, and N.

(4) $\lambda$, is a function of t which is either a polynomial, a step-function, or any other convenient form. This is the arrival rate of passengers seeking transportation and is essentially the kinematic requirements function described elsewhere in this report.

Outputs from the Flow Diagram

(1) The main output is the frequency of people over waiting time. This can be shifted by an amount equal to travel time and become the kinematic performance function under the set of input parameters that have been used.

(2) Final queue. Whether or not a final queue exists depends on two factors: First, whether or not there are passenger arrivals beyond the time of the last vehicle departure and second, whether or not there were people in the queue for whom there was no available capacity in the final vehicle departure.

(3) Queue table. This is a separate table, not central to the main computations. It consists of the number of people at each vehicle departure who were unable to get on the vehicle because it was full. It might be useful in the psychological evaluation of the system and in other ways, also.

It is quite possible that both (2) and (3) would be zero in some cases. This would depend on the parameters of the problem.

## Chapter 3. Summary of Evaluation Parameters

Evaluative parameters have been suggested in regard to kinematic, engineering, economic, and psychological aspects of airport transportation. They vary considerably in form and in the amount of effort required to obtain them. As has been pointed out previously, the relative importance of the several parameters is not known. Some do appear to be more basic than others, but there are no absolute weights which can be assigned to them.

Specifically, how they should be employed in a particular case depends in part upon the question asked and upon the situation being considered. For a wide variety of situations and questions asked, however, it is felt that the set of parameters suggested provide a useful and powerful set of tools to accomplish a comprehensive assessment.

A summary and recapitulation of the suggested parameters follows.

Kinematics: Comparison of the distribution of travelers' trip times over time generated by each system. The comparison can be one system with another or each system against a criterion distribution. These comparisons reflect the differences among systems in their abilities to move the loads required of them. The data can be empirically determined or generated through simulation or analytic techniques. (See Part III, Chapter 1.)

Engineering: Several parameters are suggested, among which are (see Part III, Chapter 2):

Vehicle capacity
Travel times — These three together form
Headway

the input data for the generation of kinematic performance distributions. They may or may not have meaning in and of themselves depending upon what information is of interest.

Way-capacity: number of units carried per unit time.

Vehicle-way capacity: maximum number of passengers carried per unit time which is the product of vehicle capacity and way capacity per unit time.

Average speed: normally, our interest is in time rather than speed. Cruising speed of the vehicle and average speed on the way are important considerations for some purposes. The average speeds of most rubber-tired vehicles are severely limited by the congestion through which they must travel.

Gross power requirement: an index can be calculated from vehicle gross weight and average velocity.

Payload power requirements: an index is calculated from capacity, power, and range for a given vehicle velocity.

Working rates: these are an indication of over-all performance efficiency; i. e., the ability to move a given load, a given number of miles, in a given period of time with a given amount of horsepower. Working rates can be calculated from cruising speed and payload power requirements.

Economics: A new parameter was devised in this area, namely, equivalent service defined in terms of fare and trip time. The indices for a given system can only be calculated relative to some other system. Thus, the changes required in the fare or trip time of mode A in order for A to produce a service of equal value to mode B can be computed. Such indices can be calculated for different monetary values of time, thus permitting the comparison of service provided for passengers of different incomes. Essentially, the indices reflect differences in the

value of the service provided to the consumer. One result of using these indices is the possibility of showing that modes can be differentially appropriate to people in different income levels. (See Part III, Chapter 3.)

Psychological. Psychological factors are indirectly reflected by several of the other parameters. In addition, the determinants of mode choice were considered to be the primary psychological variables subject to measurement at the present time. However, these parameters are of limited value until studies are conducted which indicate the relative importance of the several determinants suggested. The determinants of mode choice suggested included (see Part III, Chapter 4):

> Trip Purpose: the purpose of the airline trip is the appropriate purpose to consider for the airport transportation trip. It defines or delimits the variables of importance for choice of airport transportation mode.
>
> Perceived Availability of Modes: the actual choice of a mode by a traveler has meaning only in the light of among what modes he perceived he had a choice.
>
> Trip Time: the most comprehensive measure of trip time is the distribution of the trip times of arrivals at a given point over time. The distribution can be for a single run, any collection of runs, or the total set of runs. By knowing the distribution of trip times for a trip a passenger is considering, it is possible to describe his expected time in probability terms.
>
> Out-of-pocket Costs: for a given set of origin and destination points, average out-of-pocket costs for a system is

is obtained by dividi.g the total costs of all the trips to or from the airport by the number of passengers.

Comfort: consists of several factors.

(1) Average vehicle interior noise level measured in decibels and specified in terms of speech interference levels.

(2) Vibration--roughness of ride, measured in terms of amplitude and frequency of acceleration in all three dimensions.

(3) Number of mode changes required, for a total system, is defined as the ratio of number of passengers who require a mode change to the total number who use the system.

(4) Services provided--qualitative description of baggage handling procedures.

(5) Spaciousness--the product of seat width and seat spacing normalized by a factor equal to the largest value of the product obtained for all systems.

Other psychological factors were discussed, but no means of objectively quantifying them were found.

This brief recapitulation of evaluative parameters does not reflect the many potential uses of the kinematic model, for example, or the economic comparative trip time and fare indices. Some of the gaps in the list are as informative as the items listed. For example, no system cost parameter appears. As we tried to show in the chapter on economic factors in Part III, costs are not the objective, easily measured factors that they may appear to be. We could have arbitrarily adopted almost any cost accounting method, but this would have begged the question in the sense that we would already know that its application would not, in

fact, give an objective, fair evaluation to all systems. This is an area worthy of further study although it would appear to us at the present time that costs are so intimately bound up in the dynamics of several economic process that, as simple and straightforward as the question "How much does it cost?" seems, somehow it represents a case of asking the wrong question--or at least phrasing it in the wrong terms.

The specification of the evaluative parameters listed can not be construed as a final list of maximally useful and informative parameters. It is however, a beginning; and having made the beginning, the next steps include the following.

(1) Elaboration and further development of the kinematic model.

(2) Determination of the relationship between mode choice and the comparative trip time and fare indices.

(3) Determination of the relative weights, and the conditions under which the weights vary, of the psychological determinants of mode choice behavior.

(4) Experimental determination of trip time criteria.

And there are others, but these appear the most apt choices for further effort.

## PART V. GENERAL CHARACTERISTICS OF THE SOLUTIONS

The nature of airport transportation as it has been depicted in this report has certain general implications for whatever solutions may be developed.

Airport transportation faces the same basic dilemma confronting local transportation in general. The relatively low capacity, rubber-tired automobile dominates the local transportation picture at the present time, but projections into the future indicate the impossibility of road-building keeping pace with the proliferation of automobiles as we now know them. This projection coupled with the general decline of mass transit makes the serious consideration of alternatives appropriate.

The problem immediately arises as to whether or not airport transportation can be considered apart from urban transportation in general. The answer seems to be that it can be in part and in part it can not. Trips between two airports in the same city and trips between the airport and a limited number of points of highly concentrated origins and destinations need not necessarily be involved in general urban transportation. It does not appear likely, however, that special purpose airport transportation can cope with the widely dispersed and thinly concentrated origins and destinations of the majority of airline passengers independently of general urban transportation. The patterns reviewed in Part II consistently show that between 20 and 40% of the local origins and destinations of the total number of airline passengers are relatively highly concentrated in the downtown hotel district. The remainder, however, show no concentrated origins and destinations.

A number of ways of improving airport transportation have been put forward. Among these are: improvements in airport access highways, connecting mass transit systems with the airport, establishment of downtown and/or satellite terminals providing specialized transportation service to and from the airport, and the use of helicopters for airport transportation. Some of the implications for each of these suggestions can be drawn from the general nature of airport transportation.

## Access Highway Improvement

Almost any steps which can be taken to shorten the travel time of rubber-tired vehicles to the airport would lead to improvement in the situation. However, this is necessarily only a partial solution. Although it is probably necessary no matter what other steps are taken, improvement of airport roads and highways alone can not significantly change the over-all picture. The total effect on airport transportation of highway improvements will be a function of how much of the total highway system over which airport users travel are improved. From the origin-destination patterns presented earlier, it is clear that almost the entire road system would have to be improved to produce a significant total effect. But such a step is not within the province of anyone whose interest is in improving airport transportation--it is a general urban problem.

## Mass Transit

At present mass transit plays an almost negligible role in airport transportation. Proposals are made from time to time for extending transit service--buses, subways, railroads--to airports. There has been little support for these suggestions because experience seems to show that the

largest part of the air-traveling public will choose to travel by other modes if they are available. Why this is so appears to be related to several factors. Frequently mode changes are required in the mass transit trip; baggage on mass transit systems is inconvenient to handle; total trip times are apt to be slower; and transit systems are often the victims of negative attitudes.

Transit systems will probably continue to be unable to supply the kind of services air travelers demand. By their very nature, transit systems can not supply satisfactory service to the majority of airport users whose origins and destinations are widely dispersed and distributed. For the trip between the airport and the downtown concentration of origins and destinations, transit systems offer some possibilities, but whether or not they would be more desirable than some other alternative would depend upon the results of a specific evaluation for the particular location in question.

The evidence indicates that a transit system must offer the passenger a great deal to entice him from his automobile if he has one. It seems apparent that transit systems must re-vitalize their concepts of the character of the service they must provide the public before they are to become acceptable possibilities for airport transportation.

## Downtown and Satellite Terminals

A proposal which is receiving considerable attention is one which would locate an airline terminal in the downtown area. Passengers would purchase tickets, check in, and check their baggage, all at the downtown terminal. A specialized transportation service would take them to the airport itself. Other such terminals located at different points around

the city could also be established. These proposals appear to offer considerable merit, particularly to that segment of the airport user population whose local origins and destinations are in the downtown area. The extent to which they would benefit the other users, again, would depend upon an analysis which compared the trip required to go first downtown and then to the airport with the best direct means for all origins and destinations. Such an analysis may or may not show the superiority of the downtown terminal system as compared with some alternative.

Helicopters

The helicopter industry is the only one in the field which is actively and aggressively attempting to introduce and promote a new concept in airport transportation. Basically, helicopters offer a means of significantly reducing travel times through their avoidance of ground traffic congestion. This advantage may be potentially offset by two other factors: (1) headway, and (2) location of heliports in relation to local origins and destinations. Compared with the taxi or private automobile which have essentially a zero headway, the headway of scheduled helicopters is a major contributor to a passenger's total trip time because waiting time is estimated as 1/2 headway. With the helicopter service presently available at United States airports, the waiting time often exceeds the actual travel time. However, helicopters have the potential of reducing headway by several magnitudes as their load factors increase enough to justify more frequent trips.

The second major factor--heliport location in relation to passengers' local origins and destinations--is less easily overcome. Where the heliport can be placed at the point of local origins and destinations, the helicopter

appears to enjoy an inherent superiority over its nearest competitors at present. Such is the case, for example, when two airports are connected by helicopter service (assuming there is sufficient between-airport passenger volume to justify reasonable headways). It would appear from the local origin and destination patterns that service between an airport and the center of the downtown concentration of origins and destinations is likely also to be such a case (again assuming sufficient passenger volume). For passengers with origins and destinations in the outlying areas, however, the helicopter presents the same problems as any form of mass transit. Using the helicopter would mean multi-mode trips with their attendant disadvantages. For many users, it is likely that it would be as much trouble to get to the heliport as it would to go directly to the airport. To what proportion of the total airport users this would apply can be determined only by a specific analysis of the origin-destination pattern under consideration.

Helicopters, therefore, appear to offer considerable potential promise for at least a partial solution to airport transportation problems.

## New Approaches

Transportation technology is continually pushing out in new directions. New concepts in transportation are proceeding from concept to drawing board to prototype testing. Undoubtedly the future will witness the introduction of new modes of local and long-distance transportation.

Our study of airport transportation has suggested to us some of the characteristics a new system should possess for to successfully improve the transportation situation. Without pre-judging the means by

which it could be implemented, it would appear that a system could be built on a small module concept whereby a large number of relatively small, low-capacity units--some of which operate on schedules and some of which are unscheduled (and, perhaps, some of them even privately owned)--would be available to cover all points of a widely scattered pattern of origins and destinations. Distributed throughout the total area would be a set of collection and distribution points. A number of the small module units with passengers destined for some particular point would come together at a collecting point and coalesce into a larger unit which would make use of extremely high-speed transit to the destination point (which might be a distributing point from which the module units would depart independently for destinations in the near vicinity). A system of this type could combine the advantages of individual transportation modes with the advantages of mass transit systems and could eliminate some of the disadvantages of both.

Such a system, which could only be implemented as a general urban transportation system, could be an answer in the future to airport transportation problems.

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